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SUMMARY REPORT OF FINDINGS OF THE DECISION SCIENCE WORKING GROUP (DSWG)

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14. ABSTRACT
A decision science working group (DSWG) was chartered by AFRL in 2002 to assess the state-of-the-art in the application of decision support science and technology (S&T); and to recommend ways to infuse the latest technologies and methodologies into the Air Force's Information Systems S&T portfolio. This report presents a brief introduction to the field of decision science as it relates to defense command and control (C2) systems and the motivations which led to the establishment of the working group, the activities sponsored and undertaken by the DSWG are described, and the findings and recommendations of the working group are summarized.

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1.0 Executive Summary

A decision science working group was chartered in Sep 2002 by the Information Directorate (AFRL/IF) to assess the state-of-the-art in the application of decision support science and technology (S&T); and to recommend ways to infuse the latest technologies and methodologies into the Air Force's Information Systems S&T portfolio. The initial objective statement for the team reads as follows:

> *The underlying goals of the DSWG are to internalize (within AFRL) best practices in the application of Decision Science (DS), and to drive advancement in the state-of-the-art to meet AF needs. (AFRL/IF working group presentation, Sep 2002)*

One of the first actions of the IF-Directorate team was to enlist the support of experts within AFRL's Human Effectiveness Directorate (AFRL/HE). Over the ensuing months and through a series of coordination meetings, it was determined that a joint IF-HE working group should address Air Force decision-support science and technology needs. This report summarizes the activities and findings of that joint-directorate Decision Science Working Group (DSWG).

By Feb 2003 the joint DSWG team had established and agreed upon the following terms of reference:

Goal: To ensure that AFRL has and applies the necessary competence in Decision Science to address Air Force needs.

Toward achieving these goals, the DSWG will attempt to:

- ***Assess the state-of-the-art in the development of Decision Support Systems.***
- ***Investigate ways to internalize best practices in the application of Decision Science (DS) within our respective directorates.***
- ***Explore how DS can help address Air Force needs.***
- ***Focus on C4ISR.***
- ***Focus on a time-frame beginning with the near-term and extending toward JV2020.***
- ***Recommend changes to our S&T "Roadmaps" to emphasize opportunities in DS leading toward decision superiority.***
- ***Institute a process that promotes collaboration between IF and HE to satisfy technology needs and ultimately deliver more effective Decision Support Systems (DSS) to warfighters.***

During 2003, the DSWG consulted with a diverse group of experts from government, industry and academia through workshops, site-visits, personal interviews, conferences, and guest-lecturer events. The DSWG identified a broad array of relevant fields of study ranging from human-centric social, psychological, behavioral and cultural sciences to more computationally-focused, computer science and decision theoretic sciences. These disciplines each have a unique research community, domain ontology, terminology, theory, set of underlying assumptions, and perspective. The breadth of perspectives and their respective potential contributions underscore the need for interdisciplinary approaches.

Although the working group fell short of achieving all the stated goals, the DSWG is pleased to report a number of significant accomplishments:

(1) A significant numbers of the AFRL S&T staff were exposed to leading theories and research in decision making and decision-support technologies, and were given an opportunity to consult with world leaders in decision science.
(2) The majority of these DSWG activities were conducted cooperatively between the Information (IF) and Human Effectiveness (HE) directorates of AFRL. As a result, the degree of interaction between the two directorates has been significantly elevated, yielding greater understanding and the identification of numerous opportunities for future collaboration in the development of decision support systems, DS research, and exploring decision support technologies.
(3) The activities of the DSWG contributed directly to the development of a noteworthy RAND Report entitled “Implications of Modern Decision Science for Military Decision-Support Systems,” Project Air Force, 2005.
(4) A number of specific research projects have emerged from the work group activities, each in its own right extending our understanding of decision science and/or making advances in key underpinning technologies of decision support systems.

In light of the DSWG not fully achieving all of the stated objectives, and an internal assessment by the working group that the activities undertaken have proven beneficial to AFRL, a few follow-up actions are recommended:

(1) A multi-disciplinary decision science research and technology group like the DSWG should be continued to maintain the momentum that has been established in strengthening the ties across the AFRL decision science community.
(2) The activities sponsored by the DSWG to increase AFRL staff’s awareness and understanding of decision science research were very well received. With or without a DSWG, these activities should be continued and encouraged: sponsoring focused workshops in DS-related topics, hosting expert lecturers at AFRL, and conducting site visits to maintain an awareness of what other experts are doing in this field.
(3) A list of DS-related research topics was developed and is recommended as a starting point for shaping AFRL’s research and development portfolio in decision science (see section 5.0).

Drawing on the collective core competencies of both AFRL/HE and AFRL/IF together should foster a richer understanding of decision science, and in time, provide the Air Force a more robust, capable, and intuitive family of decision-support systems.

2.0 Introduction

The Decision Science Working Group (DSWG) functioned as an informally structured team of AFRL researchers active during the latter part of 2002 and throughout 2003. The team was formally chartered to investigate the broad field of decision science (or sciences), and to take actions to ensure AFRL draws upon and applies the best technologies and practices in the application of decision science (DS) in the development of decision support systems (DSS) to meet current and future AF needs.

This report summarizes the work of the DSWG starting with introductory and background information in section 2. In section 3 the principal activities undertaken by the team are described. In section 4 the working group's accomplishments are summarized, and in section 5 a set of conclusions and recommendations are presented. Finally, in section 6 a list of references are provided.

2.1. Motivation

Decision Making is a key enabler for Information Superiority as defined in Joint Vision 2020. Potential users of decision support systems include analysts, planners, and warfighters from all services and levels of responsibility. Both AFRL's Information and Human Effectiveness directorates are making significant investments in understanding and extending decision support science and technology, and developing new decision-support capabilities to improve Air Force decision making.

One of the key motivations for establishing a DS team within the Information Directorate grew from observations made by a 2001 Air Force Scientific Advisory Board (SAB) review of the directorate's Dynamic Planning and Execution thrust. The most relevant concern and recommendation voiced from that review follows:

"The C2 Decision area was, surprisingly, missing any obvious decision science and theory component.

- Area seems overly skewed towards modeling and simulation
- Broaden investigation areas to cover decision quality, decision timeliness, etc."

In response to these observations, as well as other concerns held by AFRL leadership, it was determined that a dedicated team should be established to investigate more thoroughly the current state-of-the-art in decision science, and within that context, the suitability of the AFRL science and technology portfolio. The team that was formed, their charter, and the activities undertaken are described in the sections that follow.

2.2. DSWG Charter

The Information Directorate team was established in Sep 2002 with the following objectives:

- Determine the requirement for the application of decision support science & technology in the context of AFRL/IF's broad S&T portfolio.
- Assess the state-of-the-art in the application of decision support science & technology.
- Infuse decision support technologies, methodologies and tools in the exploration, development, and evaluation of AFRL/IF's decision support products.
- Recommend changes to our S&T portfolio and culture to emphasize opportunities in decision support science & technology.

One of the first activities of the Information Directorate team was to consult with experts in the field of human decision-making from the AFRL Human Effectiveness Directorate (AFRL/HE). Based on common concerns, the degree of shared interests among the two directorates, and recognizing an opportunity to leverage personnel with complementary technical expertise, it was determined that a joint directorate (IF and HE) multi-disciplinary DSWG should be established to study this field.

Working as a cross-directorate team, by Feb 2003 the DSWG had established the following working charter:

Goal: To ensure that AFRL has and applies the necessary competence in Decision Science to address Air Force needs.

Toward achieving these goals, the DSWG will attempt to:

- ***Assess the state-of-the-art in the development of Decision Support Systems (DSS).***
- ***Investigate ways to internalize best practices in the application of Decision Science (DS) within our respective directorates.***
- ***Explore how DS can help address Air Force needs.***
- ***Focus on C4ISR.***
- ***Address Air Force needs from the near-term through JV2020 time-frame.***
- ***Recommend changes to our S&T "Roadmaps" to emphasize opportunities in Decision Science (DS) leading toward decision superiority.***
- ***To institute a process that promotes collaboration between IF and HE to satisfy technology needs, ultimately to deliver more effective DSS to warfighters.***

2.3. Team Organization / Membership

The DSWG was established as a partnership between AFRL/HE and AFRL/IF, co-lead by LtCol Cindy Dominguez (HEX), and Mr. Jerry Dussault (IFSE). A complete list of the DSWG membership is provided below (see Figure 1.)

Information Directorate (IF)	Human Effectiveness Directorate (HE)
Dr. Thomas Triscari* (IF)	Dr. Janet Miller (HECA)
Joseph Carozzoni (IFSB)	LtCol Cindy Dominguez (HEX)
Maj George Tadda (IFS)	Mr. Donald Monk (HECA)
Mr. Paul Yaworsky (IFSB)	Dr. John Reising (HEC)
Mr. Jerry Dussault (IFSE)	Mr. Samuel Kuper (HESS)
Dr. Kirk Weigand (IFSD)	Dr. Kevin Gluck (HEA)
Dr. Don Gossink** (IFT)	Lt. Mona Stilson (HESR)
	Capt. Brian Tidball (HESR)
	LtCol Mark Sheehan (HECA)

* IPA Rensselaer Polytechnic Inst.
** Visiting Researcher, DSTO, Australia

Figure 1. AFRL DSWG Membership

2.4. Summary of Planned Activities

The DSWG developed the following outline of planned activities early in 2003:

- Invite noted Decision Science Experts to lecture at AFRL-sponsored events
- Sponsor workshops, symposia, seminars, and short-courses focusing on Decision Science topics of interest
- Make Decision Science a special emphasis subject for AFRL's Information Institute, for FY03
- Team with AFRL/HE, AFOSR and others as identified, to leverage resources and world-class expertise
- Develop a knowledge base of current Decision Science activities within AFRL, other service labs, across Government agencies, industry, and academia.
- Make site visits to establishments highly regarded for their Decision Science expertise
- Supplement AFRL staff with Decision Science experts from academia, (full-, part-time, sabbatical, post-doc, etc.)

The specific actions undertaken, the findings, and recommendations from the working group are described in the sections that follow.

3.0 Summary of Activities Undertaken

Beginning in 2002 and continuing into 2003 the DSWG carried out an array of activities to address the goals identified above. The activities included:

- sponsoring and participating in workshops, conferences and seminars
- sponsoring guest lecturers
- visits to some of the leading researchers in decision science
- sponsoring/directing decision-science research projects

These activities are described in greater detail in the remainder of this section.

3.1. Workshops, Conferences, & Seminars

AFRL's DSWG members sponsored, or participated in a number of workshops, conferences, covering the field of decision science. The most noteworthy events are summarized below.

3.1.1. DSWG Kickoff Meeting, 23-24 Oct 2002 at GMU

The first significant event sponsored by the DSWG was a kickoff meeting, held 23-24 Oct 2002 at the Center of Excellence in Command, Control, Communications, and Intelligence (C3I) at George Mason University (GMU), Fairfax, VA. The purpose of this meeting was to bring together and focus research and development (R&D) representatives from the military, academia, and industry to discuss requirements, share perspectives and pool knowledge. Specific goals were to define "Decision Sciences," as seen from varying perspectives and particularly in the context of enhancing military decision making (Ref. JV2020 and AF Vision 2020), and to develop a "Way Ahead" action plan for AFRL Information (IF) and Human Effectiveness (HE) Directorates.

Speakers for the kickoff meeting were selected based upon their experience and reputation as leaders in fields supporting decision science, and for the unique expertise they could contribute to improving our collective understanding of this complex field. The list of invited speakers, their affiliation, and the title/subject of their presentation follows:

- Dr. Eduardo Salas (Univ. of Central Florida), "The Science of Team Performance in Context: Progress & Challenges"
- Dr. Jean MacMillan (Aptima), "Theory and Models: Command and Control Teams"
- Dr. Laurel Allender (ARL), "Computing Cognition: The Requirement for Models of Commanders Making Decisions"
- Dr. Dennis Leedom (Evidence Based Research), "Organizational Sensemaking"
- Dr. Richard Deckro (AFIT/ENS), "Decision Sciences in Information Operations"
- Dr. Gary Klein (Klein Assoc.), "How Information Technology Makes People Stupid"

- Dr. Andrew Sage (GMU, Dept of Sys Engr and Ops Research), "Complex Adaptive Issues and Considerations in Support of Decision Making"
- Dr. Marek Druzdzel (Univ of Pittsburgh), "Augmenting Human Decision Making Through Normative Systems"
- Dr. Eugene Santos (UConn), "Overview of Efforts at the Intelligent Distributed Information Systems Laboratory"
- Dr. Lee Ehrhart (MITRE Corp.), "Cognitive Systems Engineering: Decision-Centered Design and Evaluation"
- Dr. Jonathan Kulick (RAND), "Decision Sciences at RAND"

A complete list of participants is provided in Appendix A.

A few key *take-away* concepts from the kickoff meeting were:

- Need for a multidisciplinary approach to address decision science: AFRL/HE and AFRL/IF complement each other.
- Issue of metrics in decision making, measures should be output based rather than input or activity-based. Output metrics (e.g., decision quality or timeliness) are more difficult to define and not what we normally measure. Process metrics are important too: where we've had an impact on the process, and identifying where the leverage points are.
- Need to balance support between novice and expert decision-makers. Encourage novices to become experts.
- Avoid the pitfalls, things we do with information technology, that make users "stupid." Recognize how technology influences process and decision making (both positive and negative). Detect the ways that proposed information technology projects can interfere with expertise.
- Use Cognitive Systems Engineering (CSE) methods to create a good fit between information technology and decision makers.
- A Decision-Centered Design approach to cognitive engineering can:
    - ID the cognitive requirements of the work
    - Describe the decision strategies to be supported
    - Determine the metrics for gauging success.
- Cognitive Systems Engineering is needed at three points:
    - At the beginning, in the form of design criteria
    - During the design process, to shape the system
    - At the end, as Test and Evaluation criteria.
- The need to recognize and differentiate between different classes of problems and coping strategies: simple, complex, and wicked.
- The power of "Story Frameworks" to communicate ideas to decision makers.
- Consider four types of cognitive decision-making models with different strengths/weaknesses, all still "works in progress"
    - Goal Oriented
    - Recognition-primed decisionmaking (RPD)
    - Information Theory
    - Cognitive Dynamic

- DSWG should engage the US Army's Advanced Decision Architecture (ADA) Collaborative Technology Alliance (CTA), sponsored by Army Research Laboratory.
- Theories of shared cognition/situation awareness are not deep enough (templates not detailed enough).
- Theory of shared mental models. Drivers: Shared mental models, shared cognition, models of team performance (inputs, outputs and throughputs), naturalistic decision making (NDM).
- Teams in the Wild (naturalistic), researchers need to study decision-making teams in their natural setting – how they really make decisions.

3.1.2. Decision Science Workshop, 15-18 Apr 2003 at the Minnowbrook Conference Center

In April 2003 the DSWG with AFRL's Information Institute (II), co-sponsored a workshop on decision science; the workshop was held 15-18 Apr 2003 at the Minnowbrook Conference Center in Blue Mountain Lake, NY. The workshop focused on identifying potential research and development investment opportunities in the science and technologies that underpin predicting the behaviors of individuals and military organizations, in support of Predictive Battlespace Awareness (PBA) and the decision-making needs of the Joint Force Air Component Commander (JFACC). Emphasis was placed on exploring how Modeling and Simulation (M&S) technologies could be used to assist PBA, looking across the spectrum from requirements to calibration and validation. The specific objectives for the workshop were to:

- Refine AFRL's vision for a JFACC training, rehearsal and course of action (COA) evaluation environment.
- Recommend an R&D "way ahead" for exploratory development.
- Identify and clarify those challenge problems that warrant additional basic research.
- Promote a common understanding of and appreciation for concepts such as: PBA, Effects-Based Operations (EBO), Intelligence Preparation of the Battlespace (IPB), and Courses of Action (COAs).
- Explore interoperable friendly COA (fCOA) and enemy COA (eCOA).

The workshop participants were organized into three focus groups to explore M&S technologies that support and/or advance PBA:

1. Modeling and prediction of human, aggregate, organizational, and cultural behavior, including:
    - Human behavioral representation (HBR) technologies
    - Prior beliefs/perceptions/judgment/ideological/etc.
    - Predictive psychological and social models
    - Verification and validation of models

2. Integration of the human-element model into the information/geophysical models, including:
   - Integrating the various models:
     - Cognitive models (e.g. behavioral, cultural, perceptual, etc.)
     - Information models (e.g. internet, media broadcasts, newspapers, etc.)
     - Geophysical models (e.g. physical locations and objects such as tanks, infrastructure, etc.)
   - How to generate the eCOAs
3. COA vs. eCOA Simulation and Analysis, including:
   - Assessing fCOA versus eCOA as an integrated process
   - Assessing multiple friendly COAs against multiple enemy COAs (e.g. wargaming)
   - How to simulate forces that react intelligently to friendly actions
   - Calibration
   - Decision and visualization support
   - Validation and verification

A complete list of workshop participants is provided in Appendix B.

The results from the three focus groups listed above were presented in a general session. At that point it was determined that it would be prudent to mix and cross-fertilize the membership of the workgroups, and to proceed by refocusing the workgroups on a few specific areas of concern to CPE, namely: (1) Effects-Based Operations (EBO), (2) Course of Action (COA) development, and (3) COA analysis and selection. The three groups were given identical tasking. They were asked to work in parallel breakout sessions to respond to the following challenges:

- Identify opportunities to make Air Operations Center (AOC) warfighters more effective,
  - Identify, describe and prioritize up to 5 suggestions.
  - Emphasize capabilities that would have a positive impact.
  - Be forward thinking, the time frame is the next 3-10 years.
- Identify approaches to achieve the capability and to overcome the technical challenges (i.e., why is it difficult).

The results from these final three breakout groups were briefed to all the participants, and the recommended topics are summarized below.

Group #1 (*Main Lodge*) recommendations:

- Capability 1: Constraint-aware, continuous COAs.
- Capability 2: Team Decision Making Aids (TDMA); emphasizing support to distributed teams.
- Capability 3: Intelligent Critic for Problems Solving and Decision-making Personalization.

Group #2 (*Boathouse*) recommendations:

- Capability 1: Interoperable Framework of COAs; a capability that allows fCOA and eCOA games to be played out. Scenario generation with real world data. A new generation of technology beyond simply attrition-based war-gamming.
- Capability 2: Explanation/rationale, reporting/analysis process for COA analysis. “Point and click” drill down. COA comparison and a capability to visualize data beyond the typical temporal and/or spatial presentations.
- Capability 3: Constraint aware COA development (e.g., logistics, legal, financial, etc.).
- Capability 4: PSYOPS (non-kinetic) integration into the COA process (e.g., social, political, cultural, and “the press”).
- Capability 5: Continuous COA, “the ultimate goal.” Continuous analysis, refinement, and assessment (operational assessment), fed into the COA development process.

Group #3 (*Classroom*) recommendations:

- Capability 1: Over 5 years, systematically build low-resolution phenomenology-based model structures to inform automated metamodeling and calibration from detailed models and other “data”
- Capability 2: Refine concept of exploratory analysis and develop first-generation sophisticated tools for accomplishing it in JTF and JFACC contexts.
    - Find robust, adaptive, COAs very likely to move us in “right direction” without violating constraints.
    - As part of this, automatically track points of Red and Blue vulnerability (critical components) to suggest ways to hedge and improve robustness.
- Capability 3: Review and redefine “validation” for low-res models used in exploration. Validity relates to structure and parameter ranges, not predictive accuracy per se.
- Capability 4: Develop tools and methods to assist intelligent aggregation. Correct aggregation involves complex “averaging” over cases, parameter values, etc.

The detailed outbriefings from each of the workgroups were organized and made available to all the participants in electronic form.

3.1.3. 12th Conference on Behavior Representation in Modeling and Simulation (BRIMS), 12-15 May 2003, Scottsdale, AZ.

This annual event provides a forum for scientific and technical exchange on research in the science of human behavior representation and on the application of leading-edge cognitive science to the behavior representation challenges faced by the modeling and simulation community. Application areas of interest include training, rehearsal, analysis, acquisition, planning, experimentation, and gaming. The conference enables modeling and simulation research scientists, engineers, application users, and technical communities to meet, share ideas and experiences, identify gaps in current capabilities, discuss new research directions, and highlight promising technologies.

DSWG and AFRL members who attended:

- Kevin Gluck, AFRL/HEA (Conference Chair)
- Joe Carozzoni, AFRL/IFSF
- John Graniero, AFRL/IF (Information Institute)
- Maj George Tadda, AFRL/IFS

A key conference “take-away” was:

- The state-of-the-art in this area is still immature. Much of the work presented was in the computer science field, as opposed to human understanding and modeling human performance fields.

Recommendations: The areas covered were much broader than decision sciences. While some benefit was received, this conference is not likely to be of premier interest to those focused on decision sciences, unless there is a pressing secondary interest in modeling and simulating human behavior.

3.1.4. Tutorial on Cognitive Task Analysis (CTA), 18 Mar 03, at AFRL, Rome, NY.

Cognitive Task Analysis (CTA) refers to a broad umbrella of techniques and methods that can be employed to improve the usefulness of information technology systems by emphasizing key cognitive tasks. CTA entails a principled process for understanding user cognitive requirements and work constraints, to apply towards the design of systems. In this tutorial, the speakers introduced and explained general definitions and discussed the impact of CTA on system design. The speakers described several families of CTA methods and presented examples illustrating how they have been used.

Various methods for capturing traceable customer requirements were reviewed, including concept maps, abstraction hierarchy, Applied Cognitive Task Analysis tool (including knowledge audit methodology), knowledge elicitation interview techniques, simulation interviews, participatory design and other tricks of the trade. An in-depth exemplar was discussed, to illustrate how CTA has been used to develop a Work-Centered Support System for Air Mobility Command. This Global Weather Management system has helped AMC flight managers and weather forecasters avoid costly delays and minimize other potential impacts to tanker and airlift operations. Thorough mining and analysis of cognitive requirements helped the computer and cognitive scientist team develop an information technology system of great usefulness to AMC.

The tutorial was arranged for AFRL/IF by AFRL/HE, and the presentations were given by:

- Lt Col Cindy Dominguez, AFRL/HEX

- Dr Janet Miller, AFRL/HEC
- Mr. Samuel Kuper, AFRL/HES
- Ms. Laura Militello, (contractor) AFRL/HESR

An expanded list of AFRL/IF participants is provided in Appendix C. A complete set of the presentation charts and references were made available to all the tutorial attendees. An extensive CTA bibliography was provided, and is included in Appendix D.

3.1.5. Cognitive Systems Engineering (CSE) Seminar; 5-7 Aug 2003, at the White Eagle Conference Center, Hamilton, NY.

The purpose of this three day seminar was to train AFRL scientists and engineers on processes, tools, and techniques of Cognitive Systems Engineering (CSE), and to foster the adoption of best practices in the application of CSE to the design and development of C2 Decision Support Systems. The list of speakers included experts from academia and industry as follows:

- Dr. Robert Hoffman, Univ. of West Florida,
- Dr. Nancy Cooke, Arizona State University
- Mr. Isaac Brewer, GeoVista Center, Penn State Univ.
- Dr. Gary Klein, Klein Associates
- Dr. Wayne Zachary, CHI Systems, Inc.
- Dr. Mica Endsley, SA Technologies

Each of the six speakers, except for the last one, was given a three-hour time block in which to present and conduct interactive activities relative to their chosen topic, in a "learning-focused" atmosphere. Speakers were directed to plan their agenda to include interactive activities relative to their presented topic, so that participants could get "hands on" experience with the concepts presented. The project manager coordinated the planning of topics and activities with the speakers to ensure there would be no duplication of topics or activities. As a result of this focus and coordination the following schedule and topics were identified and adopted for the seminar.

Date/Time	*Speaker*	*Topic*
Tues. AM	Robert Hoffman	An overview of CSE, Concept Mapping
Tues. PM	Isaac Brewer	Establishing a Knowledge Elicitation Process
Wed. AM	Gary Klein	Decision-centered Design Process
Wed. PM	Mica Endsley	Designing for Situation Awareness in Complex Systems
Thurs. AM	Nancy Cooke	Team Cognition
Thurs. PM	Wayne Zachary	Cognitive Agent Development

Table 1. CSE Seminar Agenda

Participation in the CSE Seminar was by invitation only and was planned to include representatives from across the divisions and branches of AFRL at the Rome Research Site, as well as some members from the Human Effectiveness (HE) directorate from

Wright-Patterson AFB. Attendance was limited to 42 per the arrangement with the White Eagle Facility. The complete list of participants is provided in Appendix E.

In lieu of providing a hard copy notebook of briefings, a CD (titled CSE Seminar Resource Kit), was given to each participant and speakers at the beginning of the seminar. In addition to the presentations, it contained some of the tools referenced by the experts, an electronic copy of the HSIAC SOAR titled "Cognitive Systems Engineering in Military Aviation Environments: Avoiding Cogminutia Fragmentosa! ", and several articles and references recommended by the speakers. Many participants used the CD during the seminar to follow along with each speaker. At the request of other participants some hard copies of the presentations were provided at the beginning of each session.

The seminar was organized and the activities coordinated in large part by Ms. Ellen Walker of ITT, through an agreement with the Data Analysis Center for Software (DACS). A summary of the materials presented during the CSE seminar is provided in Appendix F.

3.1.6. AFOSR Decision Sciences Workshop, 16- 17 June 2003, George Mason University

The purpose of the workshop was to evaluate current research activities and identify areas in Decision Sciences that warrant further investment in basic research. Dr. Bob Sorkin/AFOSR opened the workshop stating the objectives were to:

- Explore the most effective use of science in both the human and computer domains to advance the development of decision support systems.
- Provide opportunities for AFOSR, HE, and IF to integrate their approaches and define ways to ensure that the development and application of science from these areas is working effectively towards a common goal.

Day one of the workshop consisted of two parts. During the first part of the day, presentations were given by members of the AFRL/HE, /IF and AFOSR/NL and /NM directorates, outlining the current status of work on decision support systems. The second part consisted of five working groups led by members of the expert panel. On the second day briefings were presented by each of the working groups, followed by a final session to integrate the issues identified by each of the five working groups. AFOSR indicated that they had reached their goal of having something 'in their hip pocket' should funding opportunities arise. Lists of both the research areas identified and the invited attendees are provided in Appendix G.

3.1.7. 6th International Conference on Naturalistic Decision Making (NDM6), 15-17 May 2003, in Pensacola, FL.

The International Natural Decision Making (NDM) conferences serve as an outlet and forum for the community of researchers involved in the study of problem solving, decision making, expertise, and situational awareness, aimed at solving real world problems. The NDM field focuses on studying real decision-makers in their natural settings. There was a call for developing a more generalizable theory of macro-cognition and decision-making. This year's conference was organized by Dr. Robert Hoffman of the Institute for Human-Machine Cognition (IHMC), and both Army Research Laboratory and AFRL helped to underwrite the cost of the conference. Selected leading scholars and researchers in the field presented excellent talks and topical sessions that included relevant case examples of cognitive work and task analyses, military examples of the breakdown in decision-making, situated cognition, smart heuristics, the study of expertise, expert apprenticeships, macrocognitive models in the design of complex systems, and applying NDM to real world needs.

While there was interchange and networking with attendees, the primary benefit of attending this event was listening to the world-class leaders speaking to an audience of their peers:

- Kim Vincente (University of Toronto), special guest speaker, discussed a case study entitled 'A Tipping Point in NDM: A Case Study of Radical Cultural Change in Health Care.'
- Gerd Gigerenzer , director at the Max Planck Institute for Human Development in Berlin, gave a talk entitled 'Less is More: How Smart Heuristics Work.'
- Scott A. Snook, a retired U.S Army officer, and an expert in study of military leadership and organizational systems, gave a talk on the need for situational awareness research with the example of the friendly fire shoot-down of two U.S. Black Hawks over Northern Iraq.
- Earl Hunt, a world leader in experimental/cognitive psychology, discussed an experiential method of education based on cognitive science and the studies of schools that have adopted this approach.
- William J. Clancey, Chief Scientist, Human-Centered Computing, at NASA-Ames Research Center, gave a talk on Situated Cognition.
- Jennifer Wiley, Tom Omerod, and James Shanteau discussed expertise out of context.
- Emily Roth, Laura Militello, Valerie Shalin, and Lia Dibello, and Frank Yates discussed expert apprenticeships.
- Gary Klien, Karol Ross, Brian Moon, Dave Woods, Judith Orasanu, and Mica Endsley discussed the role of Macro-cognitive models in the design of complex cognitive systems.
- Jan Maarten Schraagen and Lt Gen Rick Brown (retired) discussed applying NDM to real world needs.

This was an excellent conference. The talks, topical sessions, and poster sessions gave a wealth of information on the research going on in this field as well as the opportunity to network and make contacts with those doing similar research. AFRL participants included: Dr. Janet Miller, Dr. Kirk Weigand, and 1Lt Mona Stilson.

Recommendations: The focus of this conference has changed somewhat, from a pure naturalistic decision-making forum to a broader exploration of the human aspects of decision-making. However, the conference does not address computational decision-making issues or the challenges we face in bridging the cognitive and computational research communities. Undoubtedly the conference will continue to be interesting and well-managed, and should remain on the 'radar scope' of the AFRL decision-science community.

3.1.8. Personality and Cultural Factors in Military Gaming Workshop, 9-10 July 2003, DMSO, Alexandria, VA.

The Defense Modeling and Simulation Office held a 'Personality and Cultural Factors in Military Gaming Workshop' to determine efficient experimental methods for isolating personality and cultural predictors in performance in military-oriented synthetic environments. It is important to know whether personality and cultural variables predict performance or styles of play in synthetic environments having a military focus. The widening variety of potential military operations (e.g., combating terrorism, coalition warfare, fighting in urbanized areas, and homeland defense) makes information about human action and reaction more salient in simulations that support training, doctrine development, tactical planning, and related military needs. Threats now come from highly organized bands of criminals like narcotics traffickers, paramilitary fanatics, and terrorists, not just conventional forces with traditional military markings and modes of operation. These adversaries present "asymmetric" threats and they loom large in public anxiety, especially since September 11, 2001. A specific goal of this workshop was to develop a roadmap for new empirical research to include cross-cutting variables, potential partnerships, and applications in M&S toolsets. A framework question was: Do measured personality and/or cultural variables predict performance?

The attendees represented government, academic, and commercial sectors. On the first day, candidate theories and instruments for personality and cultural assessment were reviewed. Important applications such as command and control, and adversarial decision making were illustrated; and computer-based games (or synthetic environments) with a military focus were discussed. On the second day, breakout groups formulated strategies for gathering empirical data linking personality and cultural factors with wargame performance and style of play. Four breakout groups were organized around the following topics:

- The use of cultural and personality data in representative classes of military models and simulations.
- The research strategies and methods used for producing these data.
- Candidate synthetic environments in the commercial marketplace and government locations that might support a gaming testbed strategy.

- Test and evaluation criteria for determining the validity and utility of given research designs and applications of data in military modeling and simulation techniques.

The goal was to achieve a consensus on which personality/cultural dimensions are most relevant for study, which instruments are most useful, and how these might be related to performance sampled through wargame simulators.

Recommendations: While the focus of discussion included considering culture and other human attributes that affect decision-making, much of the discussion centered around the proposal that DMSO should have a test-bed using commercial games to simulate our antagonists' actions for training and rehearsal purposes. No follow-up AFRL action is recommended.

3.2. Guest Lecturers

In an effort to expose some of the latest concepts and technologies in decision science to the broader R&D community at AFRL, the DSWG sponsored a number of guest lecturers at the Rome Research Site. A listing and brief summary of a few of the key presentations is provided below.

3.2.1. Carmel Domshlak, Ph.D., Cornell University; Aug 2003.

Title: The Success, Failure, and Promise of Decision Theory

The ability to make decisions and to assess potential courses of action is a corner-stone of many artificial intelligence (AI) applications, including expert systems, autonomous agents, decision-support systems, recommender systems, configuration software, and constrained optimization applications. To make good decisions, we must be able to assess and compare different alternatives, and thus explicit information about the decision-maker's preferences is required.

The field of decision theory and its companion methodology of decision analysis deal with the merits and making of decisions. As developed by philosophers, economists, and mathematicians over some 300 years, these disciplines have developed many powerful ideas and techniques, which exert major influences over virtually all the biological, cognitive, and social sciences. In spite of these remarkable achievements, the tools of traditional decision theory have not proven fully adequate for supporting recent attempts in artificial intelligence to automate decision making. The main problem is that extracting preference information from users is generally an arduous process, and human decision analysts have developed sophisticated techniques to help elicit this information. A key goal in the study of computer-based decision support systems is the construction of tools that allow the preference elicitation process to be automated, either partially or fully. Methods for extracting, representing, and reasoning about the preferences of naive users are particularly important in artificial intelligence (AI) applications, whose users cannot be expected to have the patience and/or the ability to provide detailed preference relations.

In this talk, a high-level overview of the multi-disciplinary achievements in the field of decision theory was presented, and the speaker addressed the attractiveness and shortcomings of numerous advancements with respect to building automated decision-support systems. The tutorial was presented at a technical level suitable for a general audience interested in decision support systems, and it was intended to introduce non-specialists to an AI area of emerging importance.

Carmel Domshlak is a post-doctoral fellow working with the Intelligent Information Systems Institute at Cornell University. His research focused on modeling and reasoning about preferences, as well as on exploiting structural properties in probabilistic reasoning, planning, and some other areas. His Ph.D. in computer science from Ben-Gurion University (Israel) was for his work on preference representation models, and he has published numerous scientific papers in this research area.

3.2.2. Selmer Bringsjord, Ph.D., Rensselaer Polytechnic Institute.

Title: Multi-Agent Reasoning and Mental Metalogic (MARMML) Reasoning System

Professor Bringsjord is the chair of the Department of Cognitive Science at Rensselaer Polytechnic Institute, Troy, NY. He is also a professor of Computer Science and Cognitive Science. He conducts research in Artificial Intelligence as the director of the Rensselaer AI & Reasoning Laboratory (RAIR), and has authored an impressive body of work on the subjects of AI and machine reasoning. Reference: http://www.rpi.edu/~brings/

Professor Bringsjord presented an overview multi-agent reasoning challenges, their implementation of a Multi-Agent Reasoning and Mental Metalogic (MARMML) system, and the ongoing research being conducted at the RAIR laboratory.

3.2.3. Mica Endsley, President, SA Technologies.

Title: Designing to Support Situation Awareness

Ms. Endsley presented her model of situation awareness (SA) and the supporting theory (see Figure 2); and her presentation emphasized practical aspects of the system design process to improve situation awareness and avoid “SA Demons,” (e.g., common pitfalls for false assumptions). Her presentation concluded with a discussion of measuring SA, with emphasis on the Situation Awareness Global Assessment Technique (SAGAT).

Mica Endsley is a recognized world leader in the design, development and evaluation of systems to support human situation awareness and decision making, and serves as President of SA Technologies. Prior to forming SA Technologies she was a Visiting Associate Professor at MIT in the Department of Aeronautics and Astronautics and Associate Professor of Industrial Engineering at Texas Tech University.

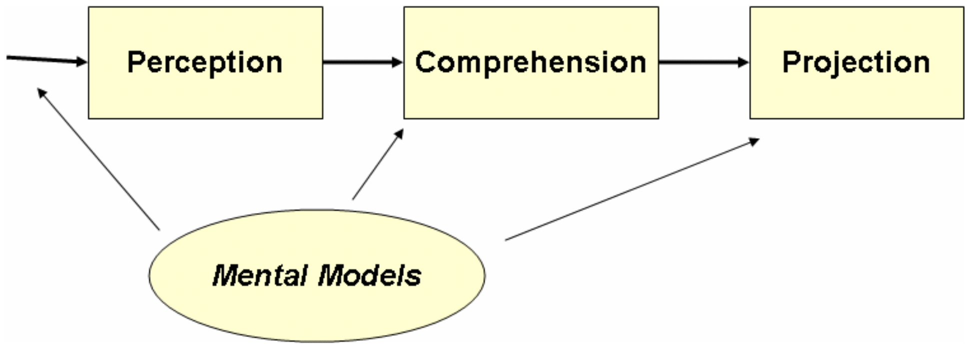


Figure 2. Simplified Endsley Situation Awareness Model

3.2.4. CTA Resource, Web-based Seminars.

In addition to those speakers who personally traveled to AFRL to lecture on topics of interest, the DSWG arranged for staff members at AFRL to participate in web-based seminars that were arranged through the "CTA Resource" online community; see http://www.ctaresource.com/. These were delivered to AFRL at no cost to the Government.

The technology employed for these online seminars enabled delivery of real-time live audio and video feeds from the speaker's location over the internet to AFRL, and concurrently to many other sites throughout the world. A number of excellent presentations were delivered; however, the quality and reliability of the audio and video feeds was at times problematic. A listing of a few of the featured presentations is provided below:

- The Empirical Comparison of CTA/CWA, Dr. Robert Hoffman.
- Field Observation Methods for Cognitive Task Analysis, Dr. Emilie Roth.
- Applied Cognitive Work Analysis, Dr. William C. Elm.
- Cognitive Task Analysis for Teams, Dr. Nancy Cooke.

Many of these and other presentations remain available via archives on the *CTA Resource* web site.

3.3. Site Visits

Throughout the lifespan of the DSWG, members of the AFRL team made site visits to a number of government, academic, and industrial research organizations seeking to extend our knowledge of specific scientific and technical topics within the field of decision science. A representative listing of visits is provided below:

- Klein Associates; Fairborn, OH. See: http://www.decisionmaking.com/
- Army Research Laboratory (ARL) Advanced Decision Architectures (ADA) Collaborative Technology Alliance (CTA); multiple meetings at various locations. See: http://www.arlada.info/.
- NASA Ames Research Center, Moffett Field, CA. See: http://www.nasa.gov/centers/ames/home/index.html.
- University of Pennsylvania (Dr. Barry Silverman), Philadelphia, PA. See: http://www.seas.upenn.edu/~barryg/
- Synergia, Redwood City, CA. See: http://www.synergia.com/.
- Stottler-Henke, San Mateo, CA. See: http://www.stottlerhenke.com/.
- Institute for Human and Machine Cognition (IHMC); Pensacola, FL. See: http://www.ihmc.us/.

3.4. Sponsored Research Projects

During the period of the DSWG investigation, AFRL sponsored a number of specific focused research projects supporting the investigation of decision science and improving decision support systems. A number of those sponsored research projects were guided by the AFRL DSWG team, and are summarized in this section.

3.4.1. Implications of Modern Decision Science and Model Abstraction Theory for the Architecture of Decision Support Systems

The objective of this project was to provide a critical review of the state-of-the-art in relevant decision science, to extend and apply research on model abstraction (and related multiresolution modeling), and to draw implications for the design and development of decision support systems. The lead investigator for this project was Jonathan Kulick, of RAND Corp. The following products were delivered:

- Davis, Paul K., Michael Egner, and Jonathan Kulick, with contributions by Robert Anderson and Lynne Wainfan, Implications of Modern Decision Science for Decision Support Systems, RAND DRR-3300, 2004.
- Bigelow, James and Paul K. Davis, Implications for Model Validation of Multiresolution, Multiperspective Modeling and Exploratory Analysis, RAND, MR-1570, 2003.
- Kulick, Jonathan and Paul K. Davis, Judgmental Biases in Decision Support for Air Operations, SPIE, 2003.
- Davis, Paul K., Thoughts on Higher-Level Adversary Modeling, SPIE, 2003.
- Davis, Paul K., Rethinking Families of Models and Games, SPIE, 2004.
- Egner, Michael and Paul K. Davis, Synthesis of Paradigms for Decision Support, SPIE, 2004.

The various documents have many implications for decision support, including the need to build in capabilities for exploratory analysis, the need to emphasize search for flexible, adaptive, and robust strategies (rather than "optimal" strategies), new ideas on multiresolution modeling and the related problem of developing families of models.

3.4.2. An Integrated Approach to Dynamic Decision Making Using Action Evaluation and Affective Symbology in Collaborative Environments, University of Dayton

The goal of this line of investigation was to improve the efficiency, effectiveness and sustainability of collaborative decision support systems. Conflicts and a gamut of problems are found when diverse groups of people try to agree on terminology as they attempt to accomplish some shared objective. The specific objective of this project was to integrate an Affective Symbolic Representation (ASR), derived from human systems, with an Action Evaluation (AE) approach that is value-driven and a Collaborative Visioning process in order to develop a dynamic decision making support system. The principal investigor was Waleed W. Smari, Ph.D., Electrical and Computer Engineering Department, University of Dayton.

A symbology was sought to represent diverse worldviews of entities so a decision support system could adapt, on-the-fly, to changes in the environment and situational factors. Actual conflict resolution work was considered with current social theory. Virtual sandplay from psychotherapy was proposed in combination with an Action Evaluation collaboration tool to reveal the complexity of intertwined worldviews. The central goal of Action Evaluation is to find a joint action plan that is acceptable from the different worldviews of the different stakeholders in a collaborative effort, to facilitate the discovery of connections between these worldviews. The action plan must be workable from the perspective of all stakeholders. Tailorability is proposed to facilitate adaptation to user needs.

At the conclusion of the DSWG reporting period this research was ongoing, under the direction of Dr. Kirk Weigand, AFRL/IFSD, (Ref. Contract# F30602-03-2-0126).

3.4.3. Efficient Campaign Plan Selection and Evaluation

A challenging research problem in the planning of military effects-based operations (EBO) is the efficient selection of action plans. Existing effects-based planning and analysis tools such as AFRL's Causal Analysis Tool (CAT) offer great promise to help planners model and analyze an effects-based plan, but offer little help to planners seeking an optimal or near-optimal plan solution. This is a technology gap that could limit the utility of tools such as CAT, and ultimately the development of EBO concepts. Under this project Dr. Ji investigated two methods to address this problem: one was a graph-theoretic approach and the other was an "action-ensemble based greedy algorithm" approach. The graphical approach was aimed at developing a theoretical basis to reduce the search space and to more methodically search for the optimal or a near-optimal plan in an efficient manner. The action ensemble based greedy approach recursively identifies an ensemble of actions to maximize the performance of an ensemble in achieving the goal. Preliminary empirical studies indicate both methods have promise in producing optimal or near-optimal solutions in reasonably bounded periods of time.

The principal investagor was Qiang Ji, Ph.D., Assistant Professor; Department of Electrical, Computer, and System Engineering; Rensselaer Polytechnic Institute. His research was conducted at AFRL during the summer of 2003, under a visiting faculty research program sponsored through the AFRL Information Institute. Professor Ji's time working at AFRL has lead to follow-on research in which he is applying dynamic bayes network concepts from this campaign planning research to challenges in dynamic information fusion under uncertainty.

3.4.4. Supporting Team Decision Processes in Adversarial Task Environments: A Multi-Disciplinary Investigation into Assessing the Functionality of Information Technologies

This research effort focused on multi-disciplinary theory development and hypotheses generation on the functionality of information technologies for team decision support in hyper-competitive environments[1]. A multi-disciplinary research team of graduate (and exceptional undergraduate) students, under the direction of the principal investigator identified the theoretic underpinnings of team-based decision systems, and then examined the theory via a priori assessment of AFRL tools for decision support. The principal investigator was Thomas Triscari, Jr. Ph.D., Lally School of Management and Technology, Rensselaer Polytechnic Institute.

Background: To gain a strategic advantage over an intelligent adversary in hyper-competitive environments, military commanders or business executives are looking toward information and computational technology to help anticipate the effects of a set of inter-related decisions (actions) and counter-decisions. For many of these decisions, the underlying processes are team-based. That is, information (which is often uncertain and equivocal) is somehow aggregated from a set of individuals within the "command staff" (or senior management) performing tasks which may be supported by information and computational technology. Despite the inherent collaborative nature of the processes, many information systems are focused on supporting individual tasks and presume the linking of individual decision aids will provide effective team support. Anecdotal evidence suggests that "information systems" designed without an understanding of human behavior in stressful situations can have dysfunctional effects on decision making performance. This suggests a multi-disciplinary (e.g., decision

[1] Hyper-Competitive Environments include those in which decisions must be made with incomplete, uncertain information; ambiguous goals; high stakes, and time-constrained, and against intelligent adversary(ies).

sciences) approach is needed to support team processes. That is, information technology must be employed in a deliberate, holistic way to support the information-intensive, team processes needed to achieve competitive advantage (e.g., information superiority) over an intelligent adversary.

Results: After conducting a thorough review of the scientific literature, and interacting extensively with the AFRL research staff over the course of the summer 2003, the Rensselaer team presented a summary of their analysis and a set of recommendations:

(A) Multi-disciplinary investigations are needed to explore the field of decision science and decision support systems (DSS) holistically.
  - (1) To achieve effective evaluation of DSS tools the system must be tested using experiments in a naturalistic laboratory environment.
  - (2) Experiments must seek to understand how human behavior and cognition effect system performance.
  - (3) Experiments must seek to understand what impact the machine would have on a team or command staff.
  - (4) A multidisciplinary team is required to design, under take, and carry out such experiments.

(B) A naturalistic adversarial task environment is needed to objectively advance our understanding of team decision making in hyper-competitive environments:

(C) Key research issues that should be addressed:
  - (1) How do we develop and evaluate decision technologies within the expanded context of decision systems?
  - (2) How can a multidisciplinary team be employed to construct decision systems that will be effective in a hypercompetitive environment?
  - (3) How can the scientific research methods be used to design, develop, and evaluate systems from a user centered, human abilities driven approach?
  - (4) What methods should be used in the design/assessment of decision systems to reduce adverse consequences?
  - (5) What organizational structure, values, and initiative will best facilitate innovative decision technology design?

A select set of presentation charts from the Rensselaer team's final briefing is provided in Appendix H.

4.0 Summary of Accomplishments

In this section the major accomplishments of the DSWG are presented, followed by a discussion of the areas in which the work group fell short of fully achieving the expected end-state.

4.1. Major Accomplishments

A brief summary of the most significant accomplishments resulting from the activities of the DSWG are presented below.

Respected authors and leading researchers in the decision science field participated in the workshops, or accepted invitations to lecture at AFRL sponsored events. As a result, significant numbers of the AFRL S&T staff were exposed to leading theories and research in decision making and decision-support technologies, and were given an opportunity to develop a network with world leading experts. While anecdotal, there is already evidence that this exposure has resulted in the internalization of new concepts and incremental improvements in our practices.

The majority of these DSWG activities were conducted cooperatively between the Information (IF) and Human Effectiveness (HE) directorates of AFRL. As a result, the degree of interaction between the two directorates has been significantly elevated, yielding greater understanding and the identification of numerous opportunities for future collaboration in the development of decision support systems and underpinning technologies.

The activities of the DSWG contributed directly to the development of a RAND Report entitled “Implications of Modern Decision Science for Military Decision-Support Systems,” Project Air Force, 2005. That monograph selectively reviews a number of key topics of relevance and interest to the development of decision support-systems, and makes a significant contribution both to our understanding of the field and in identifying opportunities to advance the state-of-practice in DSS development.

A number of specific research projects have emerged from the work group activities, each in its own right extending our understanding of decision science and/or making advances in key underpinning technologies of decision support systems:

- Implications of Modern Decision Science and Model Abstraction Theory for the Architecture of Decision Support Systems
- An Integrated Approach to Dynamic Decision Making Using Action Evaluation and Affective Symbology in Collaborative Environments
- Efficient Campaign Plan Evaluation and Selection
- Supporting Team Decision Processes in Adversarial Task Environments

4.2. DSWG Shortfalls

A brief discussion of the areas where the DSWG fell short of fully realizing the objectives is presented below.

4.2.1. Distinguished Lecture Series

Although a number of world-class speakers were brought in to lecture at AFRL under the sponsorship of the DSWG and those sessions were very well attended, due to scheduling difficulties and conflicts the number of presentations that were held fell short of our initial goals and expectations. As a result, the breadth of topics that were presented was somewhat limited.

4.2.2. Evaluating the State-of-the-Art

In an effort to better understand the state-of-the-art in decision science, one of the tasks the workgroup initiated was to develop a well organized taxonomy of the sciences and technologies that fall within the scope of “decision science.” The breadth of the topic, and the many different views of the space of decision science made this a more challenging task than was anticipated, and was never brought to closure. Additionally, the breadth of disciplines within the decision science field prevented the work group from reaching a final assessment of the states-of-the-art across the many contributing fields of science and technology. The team; however, did gain a more insightful understanding of and appreciation for the state-of-practice in the development of decision support systems, and identified a number limitations and areas of concern.

4.2.3. Computational Technologies in Decision Support Systems

The workgroup put a great deal of emphasis into the cognitive science aspects of decision science, and with limited resources, this came at the expense of a deeper exploration of state-of-the-art and current limitations in computational technologies and their application in decision-support systems. As a result, the workgroup did not investigate the role of computational technologies in decision science as broadly or as deeply as may be warranted.

4.2.4. Institutionalizing the Process

The workgroup made great strides in bringing together the personnel and diverse cultures of two different AFRL directorates to create an organization that is more capable of delivering world class decision-support systems for the Air Force. However, these gains were not institutionalized within the organization via any formal means (e.g., changes in processes). The effort of the workgroup also seems to have “infected” a broader community within AFRL with an appreciation for the potential payoffs of establishing “joint” programs across disciplines and directorates. However, this course has not yet been fully internalized and will likely require follow-up action to sustain the momentum achieved by the DSWG.

5.0 Conclusion & Recommendations

Although all the objectives set forth for the DSWG late in 2002 were not fully achieved, the efforts of the working group have paid off in a number of important ways:

- Improving the frequency and quality of the interactions across the two participating AFRL directorates in matters related to decision science.
- Highlighting the need for a multi-disciplinary perspective and cooperation in the advancement of decision science, and in the development of decision support systems.
- Exposing AFRL scientists and engineers to many of the leading experts and widely accepted scientific theories that form the foundation of our understanding of decision-making and decision support systems.
- Expanding the portfolio of decision science research at AFRL in directions that are critical to meet future Air Force decision-support needs, and doing so in ways that build smartly on an extensive established multi-disciplinary research base.

Recognizing that the DSWG did not achieve all of the objectives envisioned, the following recommendations for further action are offered:

- The DSWG served an important role in building and strengthening ties between two geographically separated communities of AFRL scientists and engineers working in the field of decision science, and while the ties have strengthened, these gains could steadily evaporate without persistent tending. Both directorates should seek ways to maintain and further increase the momentum gained by the DSWG, and consider expanding the membership or collaboration beyond that of AFRL:
    - Charter a DSWG-like working group on a long-term basis, and allocate resources annually (manpower and funding); to guide, coordinate, and report on AFRL’s progress in decision science. Within AFRL, reach out beyond the two divisions (IFS and HEC) which formed the core of the DSWG.
    - Sponsor research projects, that would require principal investigators or project managers from the two respective directorates (HE and IF) to jointly participate or manage the investigation.
    - Work collaboratively with AFOSR to jointly sponsor and direct research topics through mechanisms such as Broad Agency Announcements (BAAs).

  - Promote short-term (e.g., 2 - 6 months), temporary duty assignments related to decision science research and development, to encourage researchers to broaden their experience by working in a different AFRL directorate.
  - Establish a joint-service working group in decision science, not unlike the Decision Aids Working Group (DAWG), which served as a decision aids science and technology coordinating body for OSD through the Reliance process over a decade ago. Clearly there is much to be gained by learning from and better coordinating with DS researchers within the other services and government agencies.

- The activities sponsored by the DSWG to increase AFRL staff's awareness and understanding of decision science research were very well received. With or without a DSWG, these types of activities should be continued and encouraged:
  - Organizing joint workshops on focused DS-related topics of interest for researchers within both directorates and AFOSR, placing an emphasis on focus, workshop products, and follow-through.
  - Hosting a DS expert lecturer series at AFRL facilities, and providing access for remote participation via AFRL's corporate video-teleconferencing technology.
  - Conducting an aggressive campaign of site visits to universities, government agencies, and commercial organizations to maintain awareness of their respective research investments and expertise in DS; placing particular emphasis on collecting, organizing and sharing across AFRL all of the information collected during each site visit.

- Finally, with respect to the AFRL DS research agenda, a number of topics with high potential payoff were considered by the DSWG. The following brief consolidated list of topics is offered for consideration:
  - Mixed-initiative decision making: a holistic multi-disciplinary approach
    - Approaches and technologies to minimize the "out of loop syndrome"
    - In the context of distributed teams
    - Progressing from novice to expert
    - Supported by enduring personalized assistants/agents
  - Novel approaches for the empirical assessment of decision support
    - Human-centered engineering vice preference management
    - Quantitatively measuring decision-making performance in teams
  - Team decision making and collaboration: team / shared situation awareness (across perception, cognition and projection).
  - Formalizations and frameworks for identifying the 'value of information' and dealing with information uncertainty
  - Cultural effects and human behavior modeling: individuals, small groups, and societies
  - Beyond NP-hard: ways to better quantify or qualify problem complexity in decision making and computability.

- Unmanned Aerial Vehicle (UAV) situation awareness across teams. (Note: this application-specific topic is expected to be of high-interest in the coming years and is the subject of an Air Force SAB study.)

6.0 References

Joint Vision 2020 (JV2020), Joint Staff, June 2000.

AF Vision 2020, USAF, June 2000, [http://www.af.mil/vision]

Implications of Modern Decision Science for Decision-Support Systems, Paul K. Davis, Johathan Kulick, and Michael Egner; RAND Project Air Force, 2005.

Final Report, Sensemaking Experts Panel Meeting, 25-26 June 2002, Dennis K. Leedom, Command and Control Research Program (CCRP).

Mixied-Initiative Control of Robotic Systems, Jared Freedmand and Jean MacMillan, 2002 Command and Control Research and Technology Symposium.

Davis, Paul K., Michael Egner, and Jonathan Kulick, with contributions by Robert Anderson and Lynne Wainfan, **Implications of Modern Decision Science for Decision Support Systems**, RAND DRR-3300, 2004.

Bigelow, James and Paul K. Davis, **Implications for Model Validation of Multiresolution, Multiperspective Modeling and Exploratory Analysis**, RAND, MR-1570, 2003.

Kulick, Jonathan and Paul K. Davis, **Judgmental Biases in Decision Support for Air Operations**, SPIE, 2003.

Davis, Paul K., **Thoughts on Higher-Level Adversary Modeling**, SPIE, 2003.

Davis, Paul K., **Rethinking Families of Models and Games**, SPIE, 2004.

Egner, Michael and Paul K. Davis, **Synthesis of Paradigms for Decision Support**, SPIE, 2004.

Appendix A. DSWG Kickoff Meeting Attendance List

George Mason University
Fairfax, VA
23-24 Oct 2002

Name	Organization
Dr. Jean MacMillan	Aptima
Dr. Laurel Allender	Army Research Laboratory – HRED
Dr. Richard Deckro	AFIT/ENS
Prof. Eduardo Salas	Univ of Central Florida
Dr. Dennis K. Leedom	Evidence Based Research, Inc.
Dr. John Salasin	DARPA
Dr. Gary Klein	Klein Assoc.
Prof. Andrew P. Sage	George Mason University
Dr. Lee Ehrhart	MITRE Corp.
Dr. Marek Druzdzel	Univ of Pittsburgh
Dr. Eugene Santos, JR	Univ of Connecticut
Dr. Jonathan Kulick	RAND Corp.
Dr. Northrup Fowler, III	AFRL/IF
Dr. Thomas Triscari	AFRL/IF (RPI)
John McNamara	AFRL/IFS
Joseph Carozzoni	AFRL/IFSF
Jerry Dussault	AFRL/IFSE
Paul Yaworsky	AFRL/IFSB
Maj George Tadda	AFRL/IFS
Dr. Kirk Weigand	AFRL/IFSD
John Graniero	AFRL/IF (Information Institute)
Dr Janet Miller	AFRL/HECA
Sam Kuper	AFRL/HES
LTC Cynthia Dominguez	AFRL/HEX

Appendix B. Decision Science Workshop Attendance List

Minnowbrook Conference Center
Blue Mountain Lake, NY
15-18 Apr 2003

Name	Organization
Jerry Dussault	AFRL/IFSE
Joe Carozzoni	AFRL/IFSF
Paul Yaworski	AFRL/IFSB
Major George Tadda	AFRL/IFS
Kirk Weigand	AFRL/IFSD
Al Sisti	AFRL/IFSA
Bob Hillman	AFRL/IFTC
John Graniero	AFRL/IF/II
John McNamara	AFRL/IFS
Nort Fowler	AFRL/IF
Tom Triscari	AFRL/IF (RPI)
Todd Humiston	AFRL/IFSA
John Salerno	AFRL/IFEA
Ray Liuzzi	AFRL/IFTB
Nate Gemelli	AFRL/IFTB
Paul Phister	AFRL/IFB
Ken Trumble	AFRL/IFSC
Janet Miller	AFRL/HEC
Lt. Matt Eaton	AFRL/HESS
Eugene Santos	University of Connecticut
George Cybenko	Dartmouth College
Power, Dan	University of Northern Iowa
Lee Giles	Pennsylvania State University
Robert Herklotz	AFRL/AFOSR
Paul Davis	RAND
Mark Stephenson	SAIC
Axel Anaruk	Lockheed Martin ATL
Boulware, Douglas	AFRL/IFEA
Bello, Paul	AFRL/IFEA
Mieczylaw (Mitch) Kokar	Northeastern Univ.
John General	Synergia

Appendix C. CTA Tutorial Attendance List

AFRL
Rome, NY
18 Mar 2003

Dr. Northrup Fowler, IF (Chief Sci)
John McNamara, IFS (IFS Div TA)
Tim Busch, IFSF
Nancy Roberts, IFTB
Ray Tucker, IFS
Jerry Dussault, IFSE
Paul Yaworsky, IFSB
Mark Gorniak, IFTB
Kevin Kwiat, IFGA
Mike Wessing, IFE (IFE Div TA)
Dr. John Salerno, IFEA
Bill Gregory, IFB
Craig Anken, IFTB
Jim Collins, IFT
Brian Spink, IFGB
Joe Carozzoni, IFSF
Mark Foresti, IFTB
Dan Fayette, FSF
Bob Farrell, IFSA
Joe Antonik, IFS

Dr. Tom Triscari, IF (IPA with RPI)
Dan Daskiewich, IFTB
Virginia Ross, IFTC
Carson Bloomberg, IFSB
Don Gossink, IFSF
Maj George Tadda, IFS
Sharon Walter, IFEA
Dr. Ray Liuzzi, IFTB
Dr. John Lemmer, IFSF
William Rzepka, IFTB
James Sidoran, IFGB
Peter Rocci, IFTB

At Wright Site:
(Via Video-Teleconference)

Bill McQuay, IFSD (Branch TA)
Ken Trumble, IFSC (Branch TA)
Plus ~8 others, list not available.

Appendix D. CTA Tutorial Bibliography

Interview/Elicitation

Flanagan, J. C. (1954). The critical incident technique. Psychological Bulletin, 51, 327-358.

Hoffman, R. R. (1987). The problem of extracting the knowledge of experts from the perspective of experimental psychology. AI Magazine, 8, 53-67.

Klein, G. A., Calderwood, R., & MacGregor, D. (1989). Critical decision method for eliciting knowledge. IEEE Transactions on Systems, Man, and Cybernetics, 19(3), 462-472.

Koubek, R. J., Salvendy, G., & Noland, S. (1994). The use of protocol analysis for determining ability requirements for personnel selection on a computer-based task. Ergonomics, 37(11), 1787-1800.

Militello, L. G., & Hutton, R. J. B. (1998). Applied Cognitive Task Analysis (ACTA): A practitioner's toolkit for understanding cognitive task demands. Ergonomics Special Issue: Task Analysis, 41(11), 1618-1641.

Roth, E. M., Woods, D. D., & Pople, H. E. J. (1992). Cognitive simulation as a tool for cognitive task analysis. Ergonomics, 35(10), 1163-1198.

Performance Observation

Di Bello, L. (1997.) Exploring the relationship between activity and expertise: paradigm shifts and decision defaults among workers learning material requirements planning. In C E. Zsambok (Ed), Naturalistic Decision Making. (pp. 163-174) Mahmaw, N. J.: Lawrence Erlbaum Assoc, Inc.

Hutchins, E. (1996). Cognition in the Wild. Cambridge, Massachusetts: MIT Press.

Omodei, M. M., McLennan, J., & Wearing, A. (1997). Integrating field observation and computer simulation to analyse command and control behaviour. Workshop presented at Defence Science and Technology Organization: Fernhill, ACT.

Patterson, E.S., Roth, E.M., Woods, D.D. (2001). Predicting Vulnerabilities in Computer-Supported Inferential Analysis under Data Overload. *Cognition, Technology, and Work,3(4),*224-237.

Roth, E. M., Mumaw, R. J., Vicente, K. J. and Burns, C. M. (1997). Operator monitoring during normal operations: vigilance or problem-solving? Proceedings of the Human Factors Society 41st Annual Meeting, Albuquerque, N.M. 1997.

Mapping Semantic Space

Gordon, S. E., Schmierer, K. A., & Gill, R. T. (1993). Conceptual graph analysis: Knowledge acquisition for instructional system design. Human Factors, 35(3), 459-481.

McNeese, M. D., Zaff, B. S., Citera, M., Brown, C. E., & Whitaker, R. (1995). AKADAM: Eliciting user knowledge to support participatory ergonomics. International Journal of Industrial Ergonomics, 15, 345-363.

Novak, J. D. (1998). Learning, creating, and using knowledge: Concept maps(R) as facilitative tools in schools and corporations. Mahwah, NJ, Lawrence Erlbaum Associates.

Thordsen, M. L. (1991). A comparison of two tools for cognitive task analysis: Concept mapping and the critical decision method. Proceedings of the Human Factors Society 35th Annual Meeting, 1, 283-285.

Functional Domain Modeling

Lintern, G., & Naikar, N. (1998). Cognitive work analysis for training system design. Proceedings of the Australian Computer Human Interaction Conference OzCHI'98, 252-259.

Rasmussen, J. (1986). Information Processing and Human-Machine Interaction. Amsterdam, The Netherlands: Elsevier Science Publishing Co.

Vicente, K.J. (1999). Cognitive Work Analysis. Mahwah, New Jersey: Lawrence Erlbaum Associates.

Functional Task Modeling

Federal Information Processing Standards Publication, Integration Definition for Function Modeling (IDEF 0)

Bailey, W., Tendulkar, J. Narayanan, S., Daley, R., Wilson, K. and Pliske, D. (1998). Modeling information seeking in a corporate environment. 4th Annual Symposium on Human Interaction with Complex Systems, March 22-25, Dayton, OH

Mitchell, C. M. and Saisi, D. L. (1987). Use of model-based qualitative icons and adaptive windows in workstations for supervisory control systems. *IEEE* Transactions on Systems, Man and Cybernetics, Vol SMC 17 (4) 573-593

Sundstrom, G. A. and Salvador, A. C. (1995) Integrating field work in system design: a methodology and two case studies. IEEE Transactions on Systems, Man and Cybernetics, Vol 25 (3), 385-399

Computational Modeling

Ryder, J. M., Weiland, M. Z., Szczepkowski, M. A., & Zachary, W. W. (1996). Cognitive engineering of a new telephone operator workstation using COGNET. Paper presented at the Human Factors and Ergonomics Society 40th Annual Meeting, Philadelphia, PA.

Zachary, W., Szczepkowski, M. A., Le Mentec, J. C., Schwartz, S., Miller, D., Gwynedd, L., & Bookman, M. A. (1996). An interface agent for retrieval of patient-specific cancer information. Paper presented at the Human Factors and Ergonomics Society 40th Annual Meeting, Philadelphia, PA.

Participatory Methods

Schuler, D. and Namioka, A. (EDS) (1993). Participatory Design: Principles and Practices. London: Lawrence Erlbaum. Communications of the ACM. Special Issue: Participatory Design, 36, 4 (June 1993)

Wood, J. and Silver, D. (1995) Joint application development. New York: John Wiley & Sons, Inc.

Qualitative Methods

Howard, G. S. (1994). Why do people say nasty things about self-reports? Journal of Organizational Behavior, 15, 399-404.

Miles, M. B., & Huberman, A. M. (1994). Qualitative data analysis: An expanded sourcebook. (2nd ed.). Thousand Oaks, CA: SAGE Publications, Inc.

Pedhazur, E. J., & Schmelkin, L. P. (1991). Measurement, design, and analysis: An integrated approach. Mahwah, NJ: Lawrence Erlbaum Associates, Inc.

Cognitive Task Analysis

Klein, G. (1999). Sources of Power: How People Make Decisions. Cambridge, Massachusetts: MIT Press.

Klein, G., & Militello, L. G. (2001). Some guidelines for conducting a cognitive task analysis. In E. Salas (Ed.), Advances in human performance and cognitive engineering research, Vol. 1 (pp.161-197). Dordrecht, North-Holland: Elsevier Science Ltd.

Lesgold, A., Lajoie, S., Logan, D., & Eggan, G. (1990). Applying cognitive task analysis and research methods to assessment. In N. Frederiksen, R. Glaser, A. Lesgold, & M. Shafto (Eds.), Diagnostic monitoring of skill and knowledge acquisition (pp. 325-350). Mahwah, NJ: Lawrence Erlbaum Associates, Inc.

Neerincx, M. A., & Griffioen, E. (1996). Cognitive task analysis: Harmonizing tasks to human capacities. Ergonomics, 39(4), 543-561.

Schraagen, J. M. C., Chipman, S., & Shalin, V. L. (2000). Cognitive task analysis. Mahwah, NJ: Lawrence Erlbaum Associates, Inc.

Scott, R., Roth, E., Deutsch, S., Malchiodi, E., Kazmierczak, T., Eggleston, R., Kuper, S., & Whitaker, R. (in press). Work-Centered Support Systems: A Human-Centered Approach to Intelligent System Design. Wright-Patterson AFB, OH: Air Force Research Laboratory.

Seamster, T. L, Redding, R. E., & Kaempf, G. L. (1997). Applied Cognitive Task Analysis in Aviation. Aldershot, U.K.: Avebury Aviation Press.

Cognitive Systems Engineering/Cognitive Engineering

Andriole, S., & Adelman, L. (1995). Cognitive Systems Engineering for User-Computer Interface Design, Prototyping, and Evaluation. Hillsdale, NJ: Lawrence Erlbaum Associates, Inc.

Potter, S.S., Roth, E.M., Woods, D.D., Elm. W.C. (2000). Bootstrapping Multiple Converging Cognitive Task Analysis Techniques for System Design. In Schraagen, J. M. C., Chipman, S., & Shalin, V. L. Cognitive task analysis. (pp. 317-340) Mahwah, NJ: Lawrence Erlbaum Associates, Inc.

Rasmussen, Pejtersen, & Goodstein. (1994). Cognitive Systems Engineering. New York: Wiley and Sons.

Sarter, N.B. and Amalberti, R. (Eds.) (2000). Cognitive Engineering in the Aviation Domain. Hillsdale, NJ: LEA.

Woods, D.D., Johannesen, L., Cook, R.I., and Sarter, N.B. (1994). Behind Human Error: Cognitive Systems, Computers, and Hindsight. Crew Systems Ergonomic Information and Analysis Center (CSERIAC), Dayton, OH (State of the Art Report).

Knowledge Elicitation Review papers

Cooke, N. J. (1994). Varieties of knowledge elicitation techniques. International Journal of Human-Computer Studies, 1(41), 801-849.

Hoffman, R. R. (1989). A survey of methods for eliciting the knowledge of experts. SIGART Newsletter, 108, 19-27.

McCloskey, B. P., Geiwitz, J., & Kornel, J. (1991). Empirical comparisons of knowledge acquisition techniques. Proceedings of the Human Factors Society 35th Annual Meeting, 268-272.

Web sites with CTA-related materials

ACTA software /CTA workshops:	http://www.decisionmaking.com/
CTA discussion forum/resources:	http://www.ctaresource.com/ http://www.ctaresource.com/eMagazine/
Computational modeling:	http://www.chisystems.com/ http://www.maad.com/
Concept mapping software:	http://www.coginst.uwf.edu/
Cognitive engineering:	http://emroth.home.mindspring.com/ http://www.aegisresearch.com/ http://www.ebrinc.com/

Appendix E. CSE Seminar Attendance List

White Eagle Conference Center
Hamilton, NY
5-7 Aug 2003

Alvarez, Rebecca C., Civ, AFRL/IFSB
Barsch, Kurt W. 2Lt, AFRL/IFSA
Bello, Paul F. Civ, AFRL/IFEA
Bloomberg, Carson G., CIV, AFRL/IFSB
Blowers, Misty K. Civ, AFRL/IFEC
Boulware, Douglas M., Civ, AFRL/IFEA
DePalma, Edward L., Civ, AFRL/IFSF
Dussault, Jerry L., Civ, AFRL/IFSE
Farrell, Robert J. Jr, Civ, AFRL/IFSA
Gameros, Timothy A. Capt, AFRL/HECA
Gemelli, Nathaniel, Civ, AFRL/IFTB
Hitchings, John E., Civ, AFRL/IFSA
Hwang, Jong S., Civ, AFRL/IFSD
Hwang, Victoria Y., Civ, AFRL/IFSA
Kremer, Gul, PSU
Kuper, Samuel R., Civ, AFRL/HESS
Kwiat, Kevin A., Civ, AFRL/IFGA
LaMonica, Peter M., AFRL/IFTB
Lee, Gi, RPI
McKeever, William E., Civ, AFRL/IFTC
McKeen, David RPI
McNamara, John V., Civ, AFRL/IFS
Oleski, Paul J., Civ, AFRL/IFGC
Ray, Sibabrata, Civ, AFLR/IFGA
Reising, John M., Civ, AFRL/HEC
Richards, Dale W., Civ, AFRL/IFTB
Ritter, Jill A., Civ, AFRL/HESR
Salerno, John, Civ, AFRL/IFEA
Sheehan, Mark D., LtCol, AFRL/HECA
Spink, Brian T., Civ, AFRL/IFGB
Stilson, Mona T., 2dLt, AFRL/HESR
Thomas-Myers, Gina, AFRL/HESS
Triscari, Thomas, Civ ,AFRL/IF (RPI)
Trumble, Kenneth C., Civ, AFRL/IFSC
Wales, William, RPI
Walker, Ellen (ITT)
Wampler, Jeff L., Civ, AFRL/HESS
White, John, RPI
Wright, Robert W. Civ, AFRL/IFTB
Yaworsky, Paul S., Civ, AFRL/IFSB

Appendix F. CSE Seminar Presentation Summaries

5-7 Aug 2003

This appendix is organized in accordance with the schedule of the seminar. For each topic presented there is a brief statement about the speaker and then a sub-paragraph containing a synopsis of their presentation(s).

1. Robert Hoffman, University of West Florida (UWF)

Robert R. Hoffman, Ph.D., a Research Scientist at the Institute for Human and Machine Cognition (IHMC) of the University of West Florida, started the conference by presenting an overview of CSE and followed that with a specific presentation on a Knowledge Elicitation (KE) method called “concept mapping”.

CSE Overview

CSE seeks to address the challenge of preserving wisdom and revealing the knowledge and skills of experts. New technologies make it not only possible but relatively easy to preserve wisdom. We know how to elicit the knowledge of experts, including “tacit” and “intuitive” knowledge that has gone undocumented. We know how to preserve corporate and organizational memory. We know how to preserve knowledge in a way that makes it easy to be shared and disseminated. The plethora of methods and tools that abound may be identified under the following groups although not limited to this categorization:

- System-oriented methods
- Cognitive-oriented methods
  - Cognitive Work Analysis (CWA)
  - Cognitive Task Analysis (CTA)
  - Cognitive Functional Analysis (CWA)
- Interviewing/observing methods for knowledge elicitation
- Process tracking methods
- Conceptual methods
- Computational cognitive modeling
- System evaluation
- Descriptive approaches
- Human reliability analysis

There is no universally accepted taxonomy for CSE. Some experts see CSE as distinct from Cognitive Work Analysis (CWA) and Cognitive Task Analysis (CTA), while others view those methods as subsets of CSE.

Concept Mapping

Dr. Hoffman presented concept mapping as a tool/technique for capturing/preserving knowledge within a domain. Concept Mapping is based on a theory of knowledge, a theory of learning, research in education and research in diagrammatic reasoning. Concept Maps (Cmaps) represent knowledge in diagrams that express concepts and propositions where a proposition is the expression of the relationship between concepts. Cmaps are typically generated in conjunction with a specialized interview process, can be applied to almost any domain, and reflect various levels of sophistication (organization of information). Dr. Hoffman characterized the interview process that occurs and then showed how concept maps evolved and were actually used as part of the interface for systems in weather forecasting, and radar tracking. Following his general presentation he demonstrated how the Cmap tool, which is downloadable from the IHMC web site, can be used to facilitate the interview process and the capture of “expert” knowledge. Participants with laptops installed the Cmap tool from the Resource Kit and started working with it under Dr. Hoffman’s guidance.

2. Isaac Brewer, Pennsylvania State University (PSU)

Isaac Brewer is working at the GeoVISTA Center at Penn State University, where he is finishing his Ph.D. under the direction of Dr. MacEachren. He is focused on developing a Cognitive Systems Engineering approach to guide design of advanced interfaces that support collaborative interaction with a Geographical Information System (GIS) in emergency management situations.

A Four-Stage Approach to Knowledge Elicitation

He described/advocated a four-stage knowledge elicitation process that progresses from a simple introductory task analysis all the way through to actual event observation and verification of results. The stages were defined as:

1. Initial Task Analysis – to determine where to focus the effort
2. Work Domain Analysis – to collect artifacts and information from experts at their work location to build the Knowledge Engineer’s understanding of the domain of practice
3. Scenario Creation and Design Storyboarding - to model the domain process and provide a proposed hypotheses for the design of the prototype system
4. Event Observation (Optional) - to allow the knowledge engineer to verify the results collected from the knowledge elicitation exercises of the previous three stages, to identify inconsistencies, and to witness those special circumstances in which the system potentially breaks down that only arise during the actual events themselves.

The seminar participants were divided into seven groups and given a concept map (developed while implementing stage 2 of his process) describing the operational scenario (from various perspectives) that occurs in emergency management preparation to respond to a hurricane. Participants were instructed to “study” the concept map and “figure out” how to use it to assist in designing a prototype system. The sheer size of the map (5’ square with hundreds of nodes and propositions and 4 distinct perspectives) emphasized the complexity of knowledge represented on the map, and gave participants a sense of the reality of capturing knowledge.

3. Gary Klein, Klein Associates, Inc.

Dr. Klein, founder and Chief Scientist of Klein Associates, has devoted his career to studying how people make decisions in natural settings and under pressure and uncertainty. His presentation addresses decision-centered design, where knowledge of the key decisions to be made is what drives the design.

Decision-Centered Design (DCD)

In his presentation on DCD Dr. Klein addressed the following questions:

- What Cognitive Functions are we supporting?
- What is the rationale for a DCD approach?
- What is the process for doing DCD?
- What are some examples of DCD projects?
- How does DCD frame a Cognitive Task Analysis?

He described a collection of actions/activities (cognitive functions) that constitute macro cognition and further characterized macro cognition as a framework for carrying out cognitive systems engineering.

He defined DCD as a Cognitive Systems Engineering approach for developing IT solutions, wherein the design drivers are the key decisions users have to make. Part of the rationale for DCD is that critical decisions appear to offer more leverage than other aspects of cognition. Decision requirements are enduring aspects of the mission while tasks and equipment may change. He indicated that DCD is needed to address information overload, and the “disconnect” that often occurs between users and designers. DCD is most useful when strong cognitive activity and expertise are important for task success. He described the DCD process with a flow diagram that included several activities that used other CSE related methods such as developing decision requirements tables and implementing cognitive task analysis techniques. He discussed the significant role of metrics development as part of the DCD process with emphasis on performance improvement. Cognitive function metrics are generated during conceptual design as V&V criteria. Macro cognitive functions are used to shape the metrics (problem detection, sense making, re-planning, coordination). Cognitive Task Analysis (CTA) data is used to generate cognitive metrics.

Dr. Klein then proceeded to discuss CTA in detail. He defined CTA as the application of a family of methods and tools for gaining access to the mental processes that organize and give meaning to observable behavior. CTA results describe the cognitive processes that underlie performance of tasks, and the cognitive skills needed to perform. Expertise is the central focus of CTA. CTA is primarily valuable for tasks that depend on cognitive aspects of expertise, such as decision making and problem solving. CTA is not:

- Research into the nature of basic cognitive processes
- A prescription about how people should be thinking
- A behavioral task analysis

Throughout his talk Dr. Klein kept the participants involved by asking them questions about their work, and the relevance of his statements.

4. Mica R. Endsley, SA Technologies, Inc.

Mica Endsley is a recognized world leader in the design, development and evaluation of systems to support human situation awareness and decision making, and serves as President of SA Technologies. Her chosen topic for the seminar addresses designing for Situation Awareness in complex systems.

Designing to Support Situation Awareness

Dr. Endsley defines Situation Awareness (SA), the driver of the decision process and a key factor in determining decision quality, as "the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future". SA is also the product of processes (perception, attention, synthesis & analysis, pattern matching with long term memory) that contribute to memory. She talked about how we form mental models and described how novices develop SA versus experts. Novices and novel situations use data driven processing, while experts use a goal-driven process to develop SA. She then proceeded to describe "SA Demons" and discuss how they influence the level of SA for complex systems. Some of the demons are:

- Attentional tunneling
- Requisite Memory Trap
- WAFOS: Workload, Fatigue, & Other Stressors
- Data Overload
- Misplaced Salience
- Complexity Creep
- Errant Mental Models
- Out-of-the-Loop Syndrome

She described how we "fight" the SA demons when designing complex systems by (1) specifically identifying requirements for SA, (2) considering human factors design guidelines and standards as we design, and (3) incorporating test and evaluation procedures to measure SA into our design. She advocates using "goal-directed task analysis (GDTA)" to establish the SA requirements, but cautions that a difficult element of GDTA is distinguishing goals from physical tasks and information needs. She advocates for human-centered design over technology-centered design since it focuses on designing the technology to fit the capability of humans, not vice versa. She then went into detail about design principles for SA-oriented design. Some key points related to these principles address how uncertainty affects SA and decision making. They are:

- How information is presented is critical
- Dissonant information has a greater impact on decisions than missing data
- Format for presenting reliability or confidence matters

Her discussion of design principles relating to alarms revealed that although alarms are theoretically considered to aid SA, in reality, they often fail to aid SA, because there are too many, or there are high false alarm rates, or they have been disabled because they are a nuisance in normal operational scenarios.

SA-oriented design provides a systematic methodology and tools for enhancing SA in designing tomorrow's systems. Measurement of SA in evaluation system design options provides critical information with greater sensitivity than simple performance measures because it provides a measure of the operator's ability to dynamically integrate multiple pieces of information into a coherent picture under operational challenges. This is critical for successful performance. One measurement technique described by Dr. Endsley is called the "Situation Awareness Global Assessment Technique (SAGAT)". It is comprised of three main activities:

- At random times, freeze the exercise
- Administer a rapid battery of queries to ascertain SA at that point in time
- Score on the basis of objective data derived from the simulation/exercise.

SAGAT overcomes problems for collecting SA data after the fact, and is a direct, unbiased, objective measure of SA, which is heavily validated, but it does require interruption of the exercise/simulation. Dr. Endsley gave some examples of how SA measures are represented in a quantifiable format and the data used to modify the design concept.

5. Nancy Cooke, Arizona State University (ASU)

Nancy Cooke was accompanied by Preston Kiekel, one of her doctoral students. They have been working together in recent research and shared the presentation time addressing different aspects of team cognition. Dr. Cooke provided an overview of team cognition and then presented the Pathfinder Network Scaling technique. Mr. Kiekel followed her with a presentation on the ProNet technique for applying network scaling to sequential data.

Knowledge Elicitation Meets Team Cognition

Dr. Cooke presented an overview of Team Cognition that addressed the following questions:

- How do we get from individual knowledge to team cognition?
- What is "Team Cognition"?
- What are the challenges to assessing Team Cognition?

- What are some approaches to Assessment?

A team is defined as "…a distinguishable set of two or more people who interact dynamically, interdependently, and adaptively toward a common and valued goal/object/mission, who have each been assigned specific roles or functions to perform, and who have a limited life span of membership".

She notes that cognitive engineering directed at teams is a relatively new field of study which began in 1996. Assessment of team cognition addresses team SA and "shared mental models".

Team cognition is more than the sum of the cognition of individual team members; it emerges from the interplay of the individual cognition of each team member and team process behaviors.

Team cognition is assumed to contribute to team performance—now more than ever. Understanding the team cognition behind team performance should facilitate interventions (design, training, selection) to improve performance. Some key challenges to assessing team cognition are:

- Assumption of Homogeneity – Teams are, by definition, heterogeneous. This complicates "shared" knowledge. Shared knowledge encompasses both common and complementary knowledge, and shared perspectives.
- Elicitation is limited to the individual level
- Assessment is valuable to the extent that it is conducted in real-time and embedded in task execution (requires automated measures), or better yet, prior to task execution (based on performance precursors)

Approaches to Assessments

Two types of metrics are typically used in assessments: (1) Holistic metrics that elicit at the team level (e.g. consensus assessment tasks), and (2) Collective metrics that elicit at the individual and aggregate to estimate the team level. Experiments at their laboratory have resulted in the following findings:

- Collective measures predict team performance for co-located teams better than holistic metrics
- Holistic metrics based on the consensus tasks predict performance better for distributed teams.
- Consensus measures correlate moderately with performance compared to collective measures.

Communication Analysis is a response to holistic assessment for operational environments. Dr. Cooke views this as a solution because (1) it is real time, embedded in the task, (2) it is observable, (3) it reflects team cognition at the holistic level, and (4) it is rich and multidimensional. However it requires labor intensive transcription and coding.

In summary the key points to remember about team cognition are:

- Understanding team cognition is critical for diagnosis of team dysfunction or excellence and later intervention with training, technology, or team composition.
- In operational environments diagnosis needs to be real-time, task-embedded, predictive, and automatic.
- Need to move toward diagnosis by connecting clusters of symptoms to diagnosis of team dysfunction or excellence.

Pathfinder Network Scaling: Representing Knowledge for Individuals and Teams

Pathfinder is a conceptual KE method that takes as input pair wise estimates of relatedness (i.e., proximities) and generates network representations of nodes and links. Concepts are represented as nodes and conceptual relations as links between nodes. The idea is to reduce the estimates in a psychologically meaningful way. It thus seeks to address the "goodness" of the knowledge. It is predicated on semantic network theory which assumes that semantics or meaning is represented symbolically as a network of interconnected concepts. The concept set and referent structures are critical to the success of this method. Pathfinder can be used to:

- Elicit Knowledge of Experts and Novices
- Investigate Subtle Knowledge Differences Among Experts
- Assess Student Knowledge

Dr. Cooke demonstrated a tool called KNOT which implements the pathfinder technique.

Applying ProNet to Communication Analysis

ProNet, which stands for "Procedural Networks" is a technique for eliciting knowledge by tracking and analyzing sequences of behaviors or events. The technique is useful for tracking:

- Communication turn-taking sequences to assess information flow strategies
- Individual task sequences of experts and novices, by comparison
- Task sequences associated with high productivity
- Procedural knowledge that experts cannot express directly

Key factors that motivate use of this technique are:

- Elicitation of procedural knowledge
- Automatic (after nodes defined)
- Descriptive, and hence robust
- Straightforward data reduction
- Possible graphical depiction

It attempts to identify sequences of prominence and does not require lots of data. Preston conducted a wonderful "hands-on" exercise to communicate the ProNet technique. Participants were divided into groups of four with three people talking and the fourth person recording the speech start and stop times (the nodes) of each of the individuals as they spoke. The communication sequences were then graphed and the audience got to see the variation in communication patterns that was occurring.

When ProNet is applied to communication data it:

- Can describe high-level phenomena from low-level data
- Is very automatic (after node choice)
- Does not require vast data sets
- Is predictive of performance
- Could be used in real-time

6. Wayne Zachary, CHI Systems, Inc.

Dr. Wayne Zachary is an internationally recognized leader in the human issues associated with the design and analysis of interactive information and decision support systems in general and with cognitive agent design and development in particular. His seminar presentation is about Cognitive Agent Development.

Cognitive Agents and Cognitive Agent Development using COGNET/iGEN

Dr. Zachary defined Cognitive Agents as "embedded or self-activated software entities that support, train, automate, or simulate cognitive work". They are applied in:

- Training and Tutoring Systems – They can function as virtual tutors, doing process assessment, provide coaching and feedback, and instructional sequencing; they can act as synthetic teammates or co-learners.
- Performance Support /Decision Support Systems – They can function as virtual mentors supporting the decision maker in managing decision flow, structuring work and decision processes, and keeping the "big picture"; they can provide intelligent electronic performance support by streamlining scale-up, increasing safety, and reducing liability.
- Engineering and Mission Simulations – They function as a simulated system user during design or acquisition, predict human performance, and predict knowledge and training that system users will need; they function as synthetic players for mission analysis or rehearsal simulations, replacing human role-players, reducing costs and increasing realism.

Following his comments about their applicability, he proceeded to discuss how cognitive agents are developed. The "take-away" message from this discussion was that one must develop agents around a specific model of human information processing and knowledge – a cognitive architecture. Specifically, use architecture as a reference point to collect human expertise, formalize it, and execute it. Then, integrate the ‘bottled’ expertise with functionality for agency (e.g., sensation, action) to create a cognitive agent.

Dr. Zachary has developed an agent-oriented cognitive modeling framework (called COGNET) that makes the connection between models, theories, and tools. COGNET models expert or near-expert levels of cognitive skill in sustained real-time/multi-tasking work. It is a *model* of how people think and act. Its purpose is to enable and simplify the creation of software systems (cognitive agents) that behave like humans in some way. It incorporates macro-level cognitive *theories* where necessary. iGEN is a COTS *toolkit* that includes a computational implementation of COGNET and tools for building and deploying cognitive agents. COGNET addresses the following principles of operation:

- Attention Focus
- Pattern-Based Attention Demand
- Attention Capture
- Task Interruption
- Cognitive Process Modification
- Perceptual Process Modification
- Multiple Task Instances

iGEN , the implementation tool for the COGNET model, provides an integrated environment for developing expertise models, competence models, and performance models using a graphical Integrated Development Environment (IDE). Once built the models can be separated and executed without the IDE as standalone or embedded cognitive agents.

Dr. Zachary provided an example of cognitive agents applied to the domain of air traffic control. We don’t see the agent; we see the effects of it working.

To get more details about COGNET and iGEN, visit this web site: www.cognitiveagent.com

Appendix G. AFOSR Workshop Summary

George Mason University
Fairfax, VA
16- 17 June 2003

Decision Sciences

The integrated list of research areas identified by the work groups is presented below:

- Behavior Moderators
- The Role of Human Emotion in Mixed Initiative Decision Making
- Adaptation to Human Differences
- Complex, Dynamic Decision Making
- Human Decision Processes in Military Command and Control
- Phase Transitions Instrumentation
- Characterization of Decision Landscape
- Measures of Difficulty of Problems
- Communicating commander (strategic) intent
- Modeling user Intent
- Problem instances and scenarios
- Research Question Identification
- Optimal Dynamic Task Allocation between Humans and Computers
- Locus of Control
- Blending of H v M Adaptation
- Hybrid Reasoning
- Decision Management
- Enhance cognitive processing
- Expertise
- Knowledge Sharing
- KB + Reasoning
- Traceability and content representation for explanation and analysis
- Visualizations and Uncertainty
- Modeling the vulnerabilities
- Dynamic filtering of massive data sources
- Modeling Team Decision Making
- Structural Adaptation of models
- Resource Quality Tradeoffs

The invited workshop attendees were:

- Kevin Bennett, Wright State University
- Jerome R. Busemeyer, Indiana University
- Jon Cagan, Carnegie Mellon University
- David Goldberg, University of Illinois at Urbana-Champagne
- Carla Gomes, Cornell University
- Wayne D. Gray, Rensselaer Polytechnic Institute
- Krishna Pattipate, University of Connecticut
- Emilie Roth, Roth Cognitive Engineering
- Edward Wegman, George Mason
- J. Frank Yates, University of Michigan

Appendix H. Summer Study Presentation Charts

Select Presentation Charts:
Supporting Strategic Decision Processes in Adversarial Task Environments

A Multidisciplinary Investigation into Assessing the Functionality of Information Technology

July 2003

Authors: Thomas Triscari, Jr., David McKeen, Gi Lee, William Wales, and John White.

Presentation Outline

Presentation Will Cover:

Changing Environment → Evolving Strategy → Technology Development → Naturalistic Laboratories

The Environment, Strategy, Technology, and Experimentation

The environment and our enemies are changing
Strategies must change to stay applicable
Decision technologies/systems must be evaluated
A naturalistic laboratory may lend such validation

Presentation Goal:

To highlight the need to revisit our decision technology development strategies due to the increased tempo and uncertainty of future hypercompetitive environments characterized by a significantly lower threshold for failure in a C2 decision system

Graduate Researchers

Presentation Introduction

- David McKeen (Adversarial Task Environments)
  - M.S. Information Technology
  - B.S. Management Science
  - Prior Experience: CIA Langley
- Gi Lee (Supporting Strategic Decision Processes)
  - M.B.A. New Product Development
  - B.S. Biomedical Engineering
  - Prior Experience: Strategic Entrepreneurial Startups
- William Wales (Assessing the Functionality of IT)
  - M.S. Information Technology
  - B.S. Information Technology
  - Prior Experience: GE Power Systems IT Development
- John White (Multidisciplinary Investigations)
  - M.S. Organizational Psychology
  - B.S. General Psychology
  - Prior Experience: Naval Air Warfare Center Training Systems Division

Defining Terminology

Presentation Introduction

- Hypercompetition
  - Multi-criteria decisions that must be made with incomplete data, uncertain information, ambiguous goals; high stakes, under time pressure, and against intelligent adversary(ies).
- Decision Technology
  - Subset of information technology that focuses on aiding the decision maker in complex situations through decision support tools and aids.
- Decision System
  - System consists of both human(s) and machine(s) that work together to enhance the performance capability of the human to effectively develop a coherent strategy in a hypercompetitive environment.
- Naturalistic Laboratory
  - A simulated real-world environment that employs a multidisciplinary team of researchers to evaluate decision technologies within the context of a decision system through observation & experimentation.

Adversarial Task Environments

- Landscape of Conflict has Changed
  - Threats, Tasks, Environments, Information/Economic/Political Warfare
- Our Enemies are Fundamentally Different
  - Values/Beliefs, Strategies, Locations, Will, Dependencies, Methods
- Changing Enemies & Landscape Yields a New Environment
  - New Models, Doctrine, Organizational Structure, decision technology

Changing Environment → Evolving Strategy → Technology Development → Naturalistic Laboratories

Changing Environment → Evolving Strategy → Technology Development → Naturalistic Laboratories

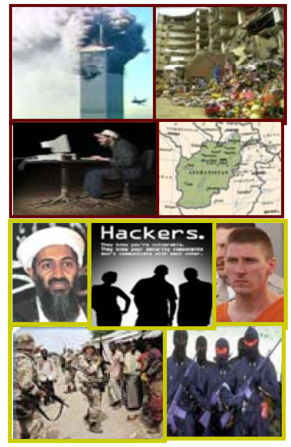
A Changing Landscape

Our Military must continue to be adaptable & capable of recognizing when the landscape of conflict has changed

	Threats	Tasks	Environment	Models	Media	Battle Space
Past (Cold War)	Few, well known (Nation States)	Focused Superpowers	Stable (U.S.S.R) Systems Untested	Many (Behavioral and Technical)	Controlled	Defined Theater Defined Enemy Motivations/ Values Structure/ Doctrine
Present	Many, Many Unknown (Nation States & Organizations)	Diverse Coalition	Volatile (Access to Knowledge) Systems Tested	Many (Technical) Few (Behavioral)	Pervasive	UnDefined Theater UnDefined Enemies Motivations/ Values Structure/ Doctrine Coalition Efforts
Future	Many, many unknown	Greater expansion of tasks	Hyper-Competitive Severe Stress On Systems	Few (Behavioral and Technical)	Invasive	UnDefined Theater UnDefined Enemies Accelerated Tempo Global Reach

The New Face of Warfare

- Threats are Additive
  - Conventional + New
  - e.g. Symmetric & Asymmetric
- Information Based Warfare
  - Info in War & Info Based Warfare
  - Economic, Political, Social Warfare
- Organizational Targeting Philosophy
  - Al Qaeda vs. Iraq
- Precise Tactical Operations
  - 1 Weapon = 1 Target + No Collateral Damage
- Effects Based Operations
  - Enemy Viewed as a System
  - Obtuse Centers of Gravity



Capabilities must evolve to match the constantly changing Threats

Changing Environment → Evolving Strategy → Technology Development → Naturalistic Laboratories

Area of Focus in C2 Support

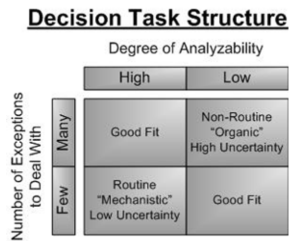
The Managerial Decision Process, Harrison, 1987

	Category I Decisions (Machine)	Category II Decisions (Human)
Decision Classifications	Programmable; routine; generic; computational;	Nonprogrammable; creative; adaptive judgmental; inspirational; innovative
Decision Structure	Procedural; structured; recurring; Certain cause/effect relationships Defined information channels Definite decision criteria Deductive Reasoning	Novel, unstructured, complex, Uncertain cause/effect relationships Incomplete information; Unknown decision criteria Perceptual Reasoning
Employed Strategy	Reliance upon rules and principles; habitual reactions; prefabricated response; uniform processing; computational techniques; accepted method for handling	Reliance on judgment, intuition, and creativity; individual processing; heuristic problem solving techniques; rules of thumb; general problem solving processes

Changing Environment → Evolving Strategy → Technology Development → Naturalistic Laboratories

Strategy Affects Decision Making

- A Measure of Effectiveness
- Yield Situational Awareness
  - Organization Analysis
  - Adversary Analysis
  - Environment Analysis
  - Rules of Engagement
- Strategy Reduces the Decision Space
  - Scope of Search Space for Relevant COAs
  - Creative and Critical Thinking Within Strategy



Making Sound and Timely Decisions is a Key Objective of the C2 Process.

Source: From Naval Doctrine Publication 6 - Naval Command and Control, 1995

Changing Environment ⇨ **Evolving Strategy** ⇨ Technology Development ⇨ Naturalistic Laboratories

Assessing the Functionality of IT

- The way we support our strategies by developing technology in this new environment will determine our success
- A true holistic approach to system development takes into account aspects of the task environment, the organization, and the individuals who comprise the systems being developed
- Human beings possess numerous abilities that decision technologies must be designed to enhance and develop
- Decision Technologies must be designed to take into account and mitigate human bias, heuristics, and cognitive limitations
- Many decision technologies focus on supporting individual tasks however decision processes are typically group based
- Decision systems must be evaluated before they are fielded to avoid unintended consequences in mission critical situations

Changing Environment ⇨ Evolving Strategy ⇨ **Technology Development** ⇨ Naturalistic Laboratories

Changing Environment ⇒ Evolving Strategy ⇒ **Technology Development** ⇒ Naturalistic Laboratories

Decision Technology Design

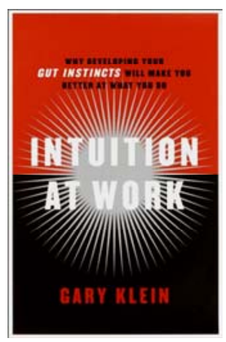
- Traditional Systems Approach
  - Machine Centered Focus
    - System Features, Execution
  - User Supported
    - GUI, Human Computer Interaction
- Meta-Systems Approach
  - Decision System Defined as Human & Machine
  - Expanded Context in Which Systems are Evaluated
  - Human-Machine Context Registration (Enabling Mixed Initiative)
  - Human Abilities Viewed as Focal to a User Centric Focus

An Uncertain Environment
"One cannot have a prepared list of rules for all possible situations, for the same reason that the immune system cannot keep a list of all possible invaders." – John Holland

The Human is an integral part of the system itself, not an external actor
The System is part of a greater organizational framework and task environment

Changing Environment ⇒ Evolving Strategy ⇒ **Technology Development** ⇒ Naturalistic Laboratories

Possible Effects of Technology *(Gary Klein)*



- Unintended Adverse Effects of IT on Humans
  - ➜ IT reduces our will and need to learn
  - IT abstracts individuals from the underlying process
  - IT prevents individuals from finding the data they need
  - ➜ IT discounts individual expertise
  - IT disrupts human pattern recognition
  - IT disrupts process knowledge of how things work
  - IT can actually create an unadaptive organization
- What Human Abilities are being Eroded?
  - The ability to sense of what are reasonable goals
  - The ability to determine trends and relevant analogues
  - ➜ The ability to actively process data into information and understanding
  - The ability to determine what additional information is required
  - ➜ The ability to notice opportunities / critical decision points

Gary Klein has identified human sources of power after 30+ years of research

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Human Abilities in Decision Systems

Trying to squeeze more productivity from a shrinking investment in human expertise will not help prevent the kinds of incidents and accidents that are currently being labeled as human error (FAA, 1996).

- Expertise, Intuition, Recognition
- Pattern Matching, Adaptability, Spontaneity
- Learning, Trust, Bias, Heuristics
- Perception of the Environment
  - Applicability of Previous Experiences
  - Assessing Changes in the Landscape of Conflict
  - Ex. September 11th 2001, United Airlines Flight 93

Understanding how the human cognitively engages the decision team & supporting technology is fundamental to developing effective decision systems.

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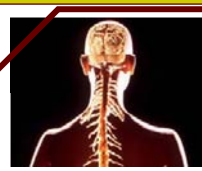
Defining & Creating Expertise

"One of the myths about the impact of automation on human performance is as investment in automation increases, less investment is needed in human expertise. In fact, many sources have shown how increased automation creates new knowledge and skill requirements." - Dr. David Woods

- Amount of Experience ≠ Expert
- Large Knowledgebase ≠ Expert
- Environmental Perception ≠ Expert
- High Performance Level ≠ Expert
  - Area of a Trapezoid
  - Karl Gauss (arithmetic series)
    - $$\sum_{k=1}^{n} k = \frac{1}{2}n(n+1)$$



Where do you invest to create expertise? **Both**

Can expertise be encoded? **NO.**

Human Centered Holistic Approach

Expertise is a function of knowledge, aggregated experiences, environmental adaptability, and behavioral performance

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Team Functions to Support

- Decision technologies are typically designed to support individual tasks however in many situations the underlying decision process is team based.
- Organizational performance thus relies on the effective linking of human decision makers all supported by individual decision aids.

How do you assess the functionality of a decision technology in this context?

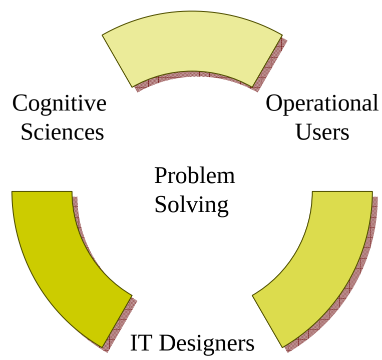
Multidisciplinary Investigations

- To achieve effective evaluation of DSS tools the system must be tested using experiments in a naturalistic laboratory environment
- Experiments must seek to understand how human behavior and cognition effect system performance
- Experiments must seek to understand what impact the machine would have on a team or command staff
- A multidisciplinary team is required to design, under take, and carry out such experiments

Changing Environment → Evolving Strategy → Technology Development → Naturalistic Laboratories

Multidisciplinary Team Importance

- Multi-Domain Problems
  - Linking Domain Experts
  - Holistic System Development
  - Consider All Env. Factors
  - Speed up Research Cycle
- Reduce Unintended Consequences
  - Human(s)/Technologies
  - Achieve Scientific Validity



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A Research Issue

"Unintended consequences are the result of focusing 80% of our effort on intended effects and only 20% on unintended while the reverse ought to be the case" Col Jose Negron *GMU EBO Workshop*

Problem:
The Laboratory w/o Naturalistic Lab --> The Field = Unintended Consequences

Solution:
The Laboratory + Naturalistic Lab + The Field = Predictive System Evaluation

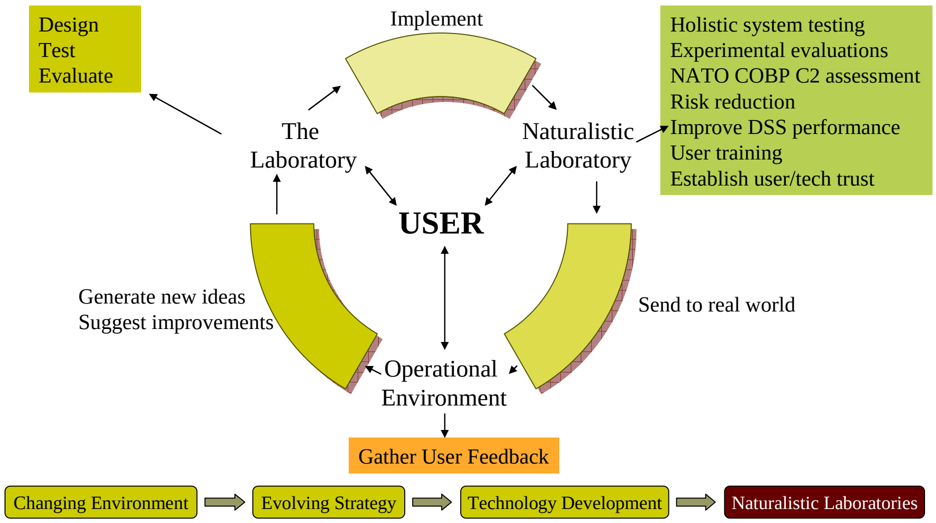
Designs, Develops, and Evaluate DSS functionality

Scientifically studies Decision Systems in a controlled simulated real world environment

Implements Decision Technology in real world environment & gathers user feedback

Changing Environment → Evolving Strategy → Technology Development → Naturalistic Laboratories

The Research Cycle



Presentation Take-Aways

Presentation Summary

- Adversarial Task Environments
  - The landscape of conflict has changed
  - Our enemies are fundamentally different
- Supporting Strategic Decision Processes
  - Our strategies must evolve to stay applicable in a rapidly changing environment
  - Decision systems must develop strategies to fight an uncertain environment
- Assessing the Functionality of Decision Technology
  - DSS must be human centric and view the system as both human(s) and machine
  - DSS must be evaluated to avoid unintended consequences in critical situations
- Multidisciplinary Investigations
  - Decision systems should be tested using scientific experimentation
  - A multidisciplinary team is required to design and carry out such experiments

If the tempo and uncertainty of a hypercompetitive environment is yielding a future where the room for error & threshold for failure in a command and control decision system is significantly less.
Then Our decision technology development strategies must be revisited.

An Actionable Briefing

Future Recommendations

- Future Picture *(C2I Advanced Futurecasting Environment - CAFÉ Vision)*
  - Recognition on a national level that AFRL/IF is the place where
    - "The C2I realities of tomorrow are being created today"
  - A Seamless & Synchronized Organization
  - An Increased Pace of Innovation (Exploration, Development, Evaluation, & Transition)
  - A Practical Experimental Evaluation Focus
  - Enhanced Capabilities to generate, mature, and rapidly deliver decision technologies
- Recommendations / Stepping Stones
  - How do we invest in the future?
  - First Institutionalize Best Practices (e.g., TADMUS)
  - Approach C2 decision technologies as decision systems
    - Employ multidisciplinary teams to evaluate decision performance
    - Attract field commanders and operators to partake in training exercises
    - Leverage CTCC as decision system research and evaluation center
- Importance of Academia-Lab Connection
  - Researchers Must Use Naturalistic Subjects, Systems, & Settings
  - Buy-in vs. Engagement (Go, Listen, Go Home vs. Active Engaging)
  - Offsite Evaluation Labs Will Not Significantly Alter Design Practices

"The future is not some place we are going but one we are creating. The paths to it are not found but made, and the activity of making them changes both the maker and destination." *–John Schaar*

Key Research Issues

Future Recommendations

- How do we develop and evaluate decision technologies within the expanded context of decision systems?
- How can a multidisciplinary team be employed to construct decision systems that will be effective in a hypercompetitive environment?
- How can the scientific research methods be used to design, develop, and evaluate systems from a user centered, human abilities driven approach?
- What methods should be used in the design/assessment of decision systems to reduce adverse consequences?
- What organizational structure, values, and initiative will best facilitate innovative decision technology design?